Faculty of Dentistry
Cairo University

TECHNICAL & CLINICAL ENDODONTICS

Edited By

Staff Members, Department of Endodontics
Faculty of Dentistry - **Cairo University**

Second Edition

CAIRO UNIVERSITY

Faculty of Dentistry

TECHNICAL & CLINICAL ENDODONTICS

Edited By

Staff Members, Department of Endodontics

SECOND EDITION

Second Edition

First Edition 2013
Reprinted 2015

"Never must the physician say the disease is incurable. By that admission he denies God; our creator; he doubts Nature with her profuseness of hidden powers and mysteries".

"Paracelsus"

DEDICATION

To

Professor Dr

SALSABYL M. IBRAHIM

The founder and pioneer of Endodontics in Egypt.

For her abundant support, patience,
understanding and endless enthusiasm.

Staff Members,
Department of Endodontics

ACKNOWLEDGMENT

A sincere acknowledgment to
all authors and members of department of endodontics for their efforts in presenting this work. Special appreciation to

Professor Dr
MAGED M. NEGM
for revising
and Dr
ALAA EL-BAZ
for refining this work.

Chairman

Department of Endodontics

PREFACE

Studies during the last decades together with clinical observations have contributed much to our knowledge in endodontics. On both biologic and clinical foundations modern endodontics has been developed. However, there is still much to be learned, and much is already known needs to be clinically applied.

Endodontic therapy, along with proper periodontal and restorative procedures, provides a basis for saving teeth. The maintenance of natural teeth can have important psychic rewards for many patients. Loss of tooth may create a tremendous psychological trauma.

New findings have been discovered relative to the pulpal and periapical diseases. Prevention of pulpal and periapical damage is an important consideration for general dentists. This book is written in the form of a guide through diagnostic procedures, treatment planning considerations, methods of prevention, methods of treatment and retreatment. As a result of these various considerations, all treatment methodologies are covered. It is hoped that this book will prove useful to the student, the general practitioner, and the endodontist. Oral surgeons, periodontists, oral pathologists, pedodontists, oral radiologists, and microbiologists may also find certain sections to be of interest in this book.

CONTRIBUTORS

Siza Yakoub
Professor of Endodontics
Faculty of Dentistry, Cairo University

Maged M. Negm
Professor of Endodontics
Faculty of Dentistry, Cairo University

Jealan Mohamed El Shafei
Professor of Endodontics
Faculty of Dentistry, Cairo University

Khaled M. Ezzat
Professor of Endodontics
Faculty of Dentistry, Cairo University

Alaa Al Din Diab
Professor of Endodontics
Faculty of Dentistry, Cairo University

Randa M. El-Boghdadi
Chairman of Department of Endodontics
Professor of Endodontics
Faculty of Dentistry, Cairo University

Mohamed Abdel-Azim
Professor of Endodontics
Faculty of Dentistry, Cairo University

Abeer Marzouk
Professor of Endodontics
Faculty of Dentistry, Cairo University

Heba El Far
Professor of Endodontics
Faculty of Dentistry, Cairo University

Angie G. Ghoneim
Professor of Endodontics
Faculty of Dentistry, Cairo University

Reem A. Lutfy
Professor of Endodontics
Faculty of Dentistry, Cairo University

Nihal E. Sabet
Professor of Endodontics
Faculty of Dentistry, Cairo University

Manar Y. Fouda
Professor of Endodontics
Faculty of Dentistry, Cairo University

CONTRIBUTORS

Ghada El Hilaly Eid
Professor of Endodontics
Faculty of Dentistry, Cairo University

Suzan Abdul-Wanees Amin
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Reham Seyam
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Alaa A. Elbaz
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Geraldine M. Ahmed
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Karim Galal Abdel-Kader
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Hend Abou El Nasr
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Abeer A. Saba
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Shaimaa I. Gawdat
Associate Professor of Endodontics
Faculty of Dentistry, Cairo University

Marwa Bedier
Lecturer in Endodontics
Faculty of Dentistry, Cairo University

Laila M. Kenawi
Lecturer in Endodontics
Faculty of Dentistry, Cairo University

Nehal Nabil Roshdy
Lecturer in Endodontics
Faculty of Dentistry, Cairo University

Sherif A. Elkodary
Lecturer in Endodontics
Faculty of Dentistry, Cairo University

TECHNICAL & CLINICAL ENDODONTICS

CONTENTS

PART (I) — THE SCIENCE OF ENDODONTICS

PART (II) — TECHNICAL ENDODONTICS

PART (III) — CLINICAL ENDODONTICS

CONTENTS

PART (IV) — RELATED ENDODONTIC TOPICS

1

PART

THE SCIENCE OF ENDODONTICS

PART I

1

Scope of Endodontics

Ghada El Hilaly Eid

Chapter Outline

Definition of endodontics

Indications for endodontic therapy

Absolute contraindications for endodontic therapy

Scope of endodontics

Phases of endodontic treatment

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define Endodontics.
2. List the phases of endodontic treatment.
3. Enumerate indications and contraindications of endodontic therapy.
4. List examples of treatment options included in the scope of endodontics.

Endodontics is the branch of dentistry concerned with the morphology, physiology, and pathology of the human dental pulp and periapical tissues. Its study and practice encompass the basic clinical sciences including biology of the normal pulp; the etiology, diagnosis, prevention and treatment of diseases and injuries of the pulp; and associated periapical conditions.

The term endodontics emerges from the Greek word "*en*", meaning in or within, and "*odous*", meaning tooth: the process of working within the tooth

Indications for endodontic therapy

Endodontic therapy provides the dentist and the patient the opportunity to save the pulp and periapically involved teeth. Any tooth from central incisor to third molar is a potential candidate for treatment.

Modern dentistry incorporates endodontics as an integral part of restorative and prosthetic treatment. Even severely broken-down teeth and potential and actual abutment teeth can be candidates for endodontic treatment. Endodontic therapy is generally indicated in:

1- **Teeth suffering pulp or apical pathology:**

   a. Pulp pathology: acute and chronic pulpitis, and necrosis of the pulp.

   b. Pulp calcification, internal resorption and external resorption. **Fig. (1)**

   c. Apical pathology: acute and chronic apical lesions. **Fig. (2)**

2- **Intentional endodontic treatment can be performed in teeth with healthy pulp in cases of:**

   a. The need for post and core construction to rebuild the missing coronal part of the tooth. **Fig. (3)**

   b. Overerupted or mesially drifted teeth when crown reduction may cause pulp exposure.

   c. Teeth retained in the mouth to retain overdentures. **Fig. (4)**

   d. Esthetic requirements .

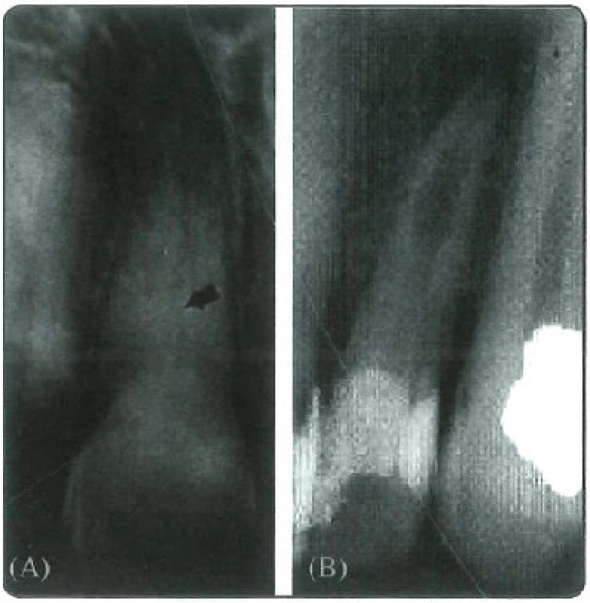


Fig. 1. Root canal calcification (A), internal resorption (B).

Fig. 2. Chronic apical lesions

   e. Crown fracture with pulp exposures, and traumatic pulp exposure during dental procedures.

Absolute contraindications for endodontic therapy

Although it is true that root canal treatment can be performed on virtually any tooth in the

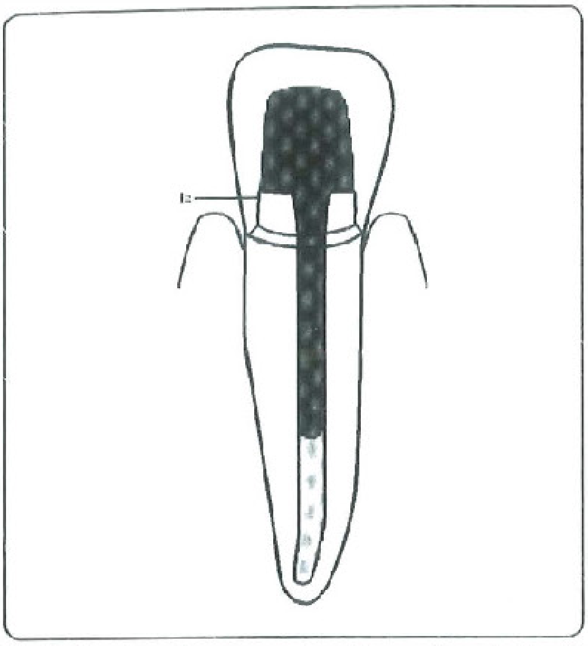


Fig. 3. Post and core restoration of endodontically treated tooth

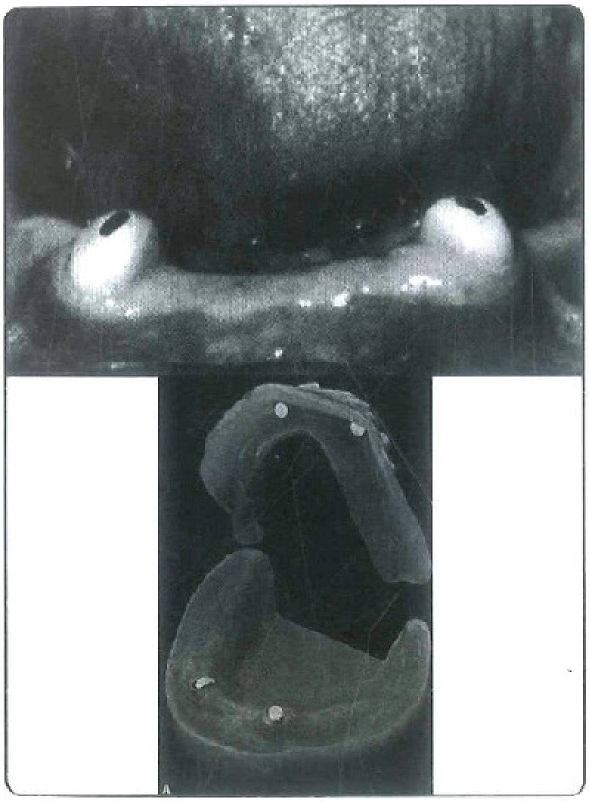


Fig. 4. Intentional endodontic treatment for retained mandibular canines for the purpose of construction of over denture

mouth, there are some important considerations that must be evaluated prior to recommending root canal treatment including:

1- Is the tooth of strategic importance?

2- Is the tooth restorable or is it badly damaged and can not be restored.

3- Is the tooth so severely involved periodontically that it would be lost so soon for this reason?

Therefore, absolute contraindications for endodontic treatment could be summarized as follow:

1- Non strategic teeth, those having no opponent, and would not serve one day as an abutment for prosthesis.

2- Non restorable teeth which can't properly function after endodontic treatment.

3- Teeth with extensive internal or external root resorption.

4- In teeth having insufficient periodontal support with severe mobility.

5- Single root teeth with vertical root fracture passing through the root canal.

The scope of endodontics

The scope of endodontic treatment options and clinically related topics can be presented as follow:

1- Differential diagnosis and treatment of oral pain of pulpal and/or periapical origin, or referred pain.

2- Vital pulp therapy (pulp capping, pulpotomy, treatment of immature teeth: apexogenesis, and apexification. **Fig.** (5)

3- Non-surgical treatment of root canal systems with or without periapical pathosis of pulpal origin, including obturation of these systems.

4- Selective surgical removal of periapical pathosis resulting from extension of pulpal pathosis including tooth structures: apical curettage, root-end resection, hemisection, bicuspidization, root resection, and root end filling. **Fig.** (5)

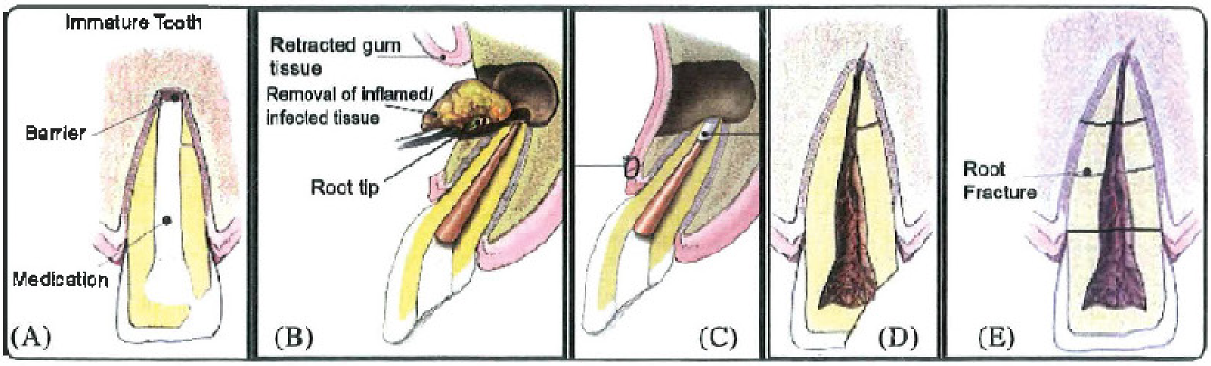


Fig. 5. Some examples of the scope of endodontic therapy. Treatment of immature tooth (A). Surgical removal of apical lesion, root-end resection and retrograde filling, (B,C) Management of traumatic injury of crown and root, (D,E)

5- Root repair procedures related to pathologic or odontoiatrogenic pathosis/damage.

6- Intentional replantation and replantation of avulsed teeth and management of other traumatic tooth injuries (luxation). **Fig. (5)**

7- Interrelationship between pulpal and periodontal diseases.

8- Endodontic endo-osseous implants.

9- Bleaching of discolored dentin and enamel.

10- Revision of previously treated root canal systems- both non-surgical and surgical.

11- Coronal restorative procedures involving the root canal space and coronal access openings.

Phases of endodontic treatment, Fig. (6)

1- **Diagnostic phase**: aims to determine the disease condition and set a treatment plan.

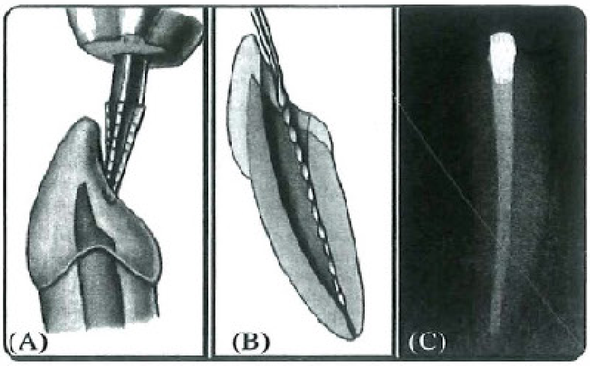


Fig. 6. Preparatory phase (coronal access opening "A", and root canal preparation "B") and obturation phase of endodontic treatment "C".

2- **Preparatory phase**: aims at gaining access to the pulp chamber and cleaning and shaping the root canals.

3- **Obturation phase**: aims at three dimensional filling of the root canals.

Chapter Review Questions

1. Define endodontics.
2. Enumerate indications of endodontic therapy.
3. Enumerate absolute contraindications of endodontic therapy.
4. Enumerate some endodontic treatment options included in the scope of endodontics
5. What are the phases of endodontic treatment?

References

- Walton RE, Torabinejad M. Principles and practice of Endodontics, W.B. Saunders company, 2015
- Cohen S, Burns R C. Pathways of the pulp, Mosby, 6th edition 1994, 8th edition 2002, 11th edition 2016.
- Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics 6, BC Decker Inc, 6th edition 2008
- Edward Besner, Andrew Michnaowicz, John Michanowics. Practical endodontics A clinical Atlas. Mosby 1994.

2

Diagnostic Procedures

Reem A. Lutfy
Suzan Abdul-Wanees Amin

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define diagnosis.
2. Identify the procedures of reviewing medical history and relate its importance to the dental procedures.
3. Identify and describe the procedures of reviewing past and present dental history.
4. Conduct the appropriate procedures of intraoral examination: visual, percussion, palpation, probing and mobility tests.
5. Consolidate all data retrieved from subjective symptoms and objective findings in differential diagnosis of pulp and/ periapical pathosis.
6. Recognize the role of radiography in endodontic diagnosis
7. Distinguish between pulp sensitivity and pulp vitality tests and correlate their findings with clinical status.
8. Criticize the various diagnostic aids applied and recognize their limitations
9. Identify and analyze the selective tests employed for difficult diagnostic clinical situations
10. Recognize recent advances that further aids in diagnosis.

Chapter Outline

Many texts have been written on diagnosis and treatment planning. All emphasize that a thorough diagnosis and determination of the cause, must be made before any definitive treatment would be considered.

Definition of diagnosis:

Diagnosis is the art of distinguishing or identifying disease. Compact Oxford English Dictionary defined diagnosis as "Elimination of the nature of a disease condition, by careful investigation of its symptoms and history".

Walton and Torabinejad stated that "in order to reach the correct diagnosis, a clear dental and medical history has to be taken, as well as performing appropriate diagnostic tests".

Simply, diagnosis means collection of data and information about a case from different sources. These data are analyzed and conclusions are brought down.

To achieve proper diagnosis, one should have:

1) ***Knowledge:*** To know, distinguish and decide when and where to refer the cases.

2) ***Interest:*** As a natural characteristic to discover disease.

3) ***Intuition:*** To suspect the unusual.

4) ***Curiosity:*** To link you with the good detective.

5) ***Patience:*** To give enough time to approach the correct diagnosis.

6) ***Sense:*** To use all physical tools; ears to hear, eyes to see and hands to palpate.

Routes of diagnosis

I- Case history (patient information)

II- Clinical examination

- a- Extraoral examination
- b- Infraoral examination
- c- Diagnostic aids

III- Laboratory investigations

I. Case history (patient information)

A) Personal data:

Patient's name, age, sex, address, telephone number, occupation, marital status should be recorded.

B) Medical history:

This includes recording the diseases and the current medications of the patient. The importance of medical history is not just prescribing medication for patients with some disease (e.g. rheumatic fever) but the problem now is more serious with the widely-spread hepatitis and sexually-transmitted diseases, e.g. AIDS, which are potentially debilitating and, even, fatal. Some medical conditions need precautions, others need consultation and some may even require hospitalization. Similarly, the drugs regularly taken by the patient should be listed because there are drugs that can cause oral manifestations (e.g. xerostomia, gingival hypertrophy...etc.), while others may contraindicate the use of other drugs for fear of drug interaction. Allergy to certain drugs should, also, be recorded.

Table (1) Medical Conditions and precaution measures

Medical condition	Precaution taken
History of infective endocarditis	Regarded as special high-risk group. Antibiotic coverage is required.
Congenital cardiac abnormality	Consider antibiotic coverage.
Rheumatic fever	May consider antibiotic coverage.
Artificial heart valves, prosthesis for total replacement of a joint	Consider antibiotic coverage.
Cardiovascular disease	GMP* to advise alteration of drug therapy. Non-surgical endodontics preferred. Analgesics to reduce postoperative pain. Stress-reduction protocol. Short and morning appointments.
Hypertension	Consult physician. Non-surgical endodontics preferred. Analgesics to reduce post-operative pain. Stress-reduction protocol. Short and morning appointments. Adjustment of anticoagulant therapy before endo-surgery.
Blood disease (Hemophilia)	Consultation (adjustment of bleeding & clotting time). Root canal treatment preferred to extraction. Hospitalization if surgery required. Local haemostatic agents (absorbable collagen/ Gelfoam). Avoid bleeding by LA** injection using shorter needles. Sequential pulp extirpation; repeated formocresol application till complete removal of fixed tissues. Avoid gingival lacerations by clamp placement; make facial & lingual notches on tooth.
Diabetes Mellitus	Blood glucose level adjustment especially before surgery. Delayed healing can be expected. Antibiotic coverage if surgery intended or infection present. GMP to advise alteration of drug therapy. Avoid epinephrine as vasoconstrictor in local anesthesia (breaks down glycogen to glucose). No aspirin prescribed as it enhances insulin action (insulin shock). Stress-reduction protocol. Short, morning and after meal appointments. Candy bar for hypoglycaemia.
Hepatitis	An infectious disease, operator is at risk of cross infection via contaminated instruments. Bleeding expected due to Vit. K deficiency. Avoid prescribing drugs detoxified in the liver. GMP to check if the patient is a carrier (Lab investigation). Precautions: 1) Vaccination for all dental personnel. 2) Rubber gloves (even double gloves), mask, eye shields, full length gowns. 3) Low speed instruments. 4) Dispose instruments after use e.g. files, burs, etc. 5) Disinfect operating area with 2% glutaraldehyde solution and place all used instruments in the solution for 1 hr before sterilization. 6) Treat at the end of the day.
Immune-suppressed states	Antibiotic coverage if infection is present.
Patients on corticosteroid or drugs to maintain organ transplants	Possible corticosteroid supplements by GMP during and after endodontic treatment.
Radiotherapy for malignant disease	Any extraction is necessary to be carried out before radiotherapy to prevent osteo-radionecrosis. Root canal treatment is preferred to extraction after therapy.

* *GMP= general medical practitioner.* ** LA = *Local Anesthesia*

(C) Past dental history:

It gives an idea about the degree of sophistication of the patient and his interest in keeping his dentition in a healthy condition. The patient's past dental experience, e.g. previous restorations or extractions, could give valuable information e.g. allergy to local anesthesia or rubber dam material, excessive bleeding following extractions, previous trauma or recurrent abscess. The dental history should include the following questions:

1- What is the patient's past total dental treatment?
2- What is the chief complaint?
3- What is the history of the chief complaint?
4- Has the patient had any recent filling?
5- Were there any unusual problems concerning the tooth, such as pulp capping, pulpectomy procedure or a large restoration performed?
6- Has the tooth ever been subject to a sharp blow in an accident of some kind?
7- Has a swelling or a gum boil around the tooth ever been noticed? If yes, what did the patient do?
8- Has there been any drainage from the tooth or gum?

Purpose: Often, the problem tooth can be localized by taking the dental history.

(D) Present dental history (chief complaint)

The chief complaint should be recorded in the patient's own words. Careful questioning of the patient must be conducted and subjective symptoms should be recorded to evaluate the patient's problem.

The following are typical questions that may be asked:

1- Is the pain present now?
2- What type is the pain (sharp/ dull/ throbbing)?
3- Is the pain localized or diffuse?
4- Is the pain intermittent or continuous?
5- What brings the pain on? Is it cold application, heat, pressure, mastication, lying down, sweet or sour foods or drinks? Or does it occur suddenly without any cause?
6- Are there any relieving factors? Analgesics, application of cold? Or is it self limiting?
7- Does it go away by itself or do you have to take medication?
8- Does hot or cold make it feel better?
9- Does the tooth feel loose? If yes, when did you first notice it?
10- How long does the pain last?

Such questions give an idea about:

- Onset of pain (sudden, gradual).
- Quality (throbbing, dull aching, lancinating).
- Duration (prolonged, short).
- Intensity (severe, moderate, mild).
- Location (diffuse, localizable).
- Course (momentary, lingering, spontaneous).
- Relieving factors (self-limiting, analgesics, cold...).
- Eliciting factors (hot, cold, lying down, biting....).
- Recurrence.

N.B.: Four words in the patient's complaint could be of significance in identifying pulp and/ or periapical conditions, namely: *tenderness, throbbing, lingering*, and *spontaneous*.

Purpose: A tentative diagnosis can often be made from the subjective symptoms.

II. Clinical examination

A) Extraoral examination:

[1] Vital signs:

Breathlessness, color changes, altered gait or unusual body movement.

- **Blood pressure:**
  Normal: Patient less than 60 years old =120 / 80 mmHg. Patient above 60 years old = 140 / 90 mmHg.
- **Pulse rate:** Normal = 60 -100 / minute.
- **Respiration Rate:** Normal = **16 -18**/ minute.
- **Temperature:** Normal = 98.6° F or 37°C.
- **Cancer Screen (if needed).**

[2] Visual inspection and bimanual palpation to examine:

- Color of the eye and face or body skin.
- Face, lips, neck and TMJ (dysfunction/ pain/ cracking sound).
- Facial asymmetry, localized swelling or sinus tracts **Fig. (1).**
- Soft tissue trauma, burns, bruises, abrasions, cuts or scars.
- Lymph node enlargement **Fig. (2).**
- Skin disease.

Fig. 1. Extraoral sinus tract.

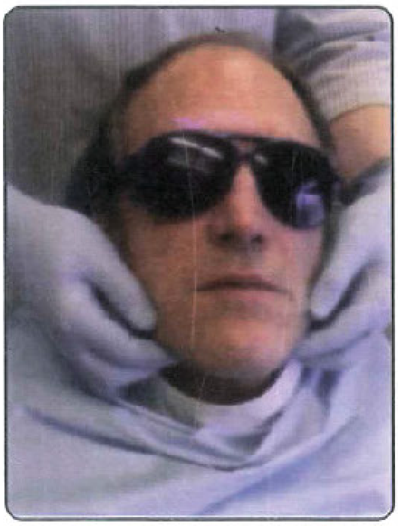


Fig. 2. Extraoral palpation to detect lymph node enlargement.

B) Intraoral examination:

[1] General examination:

Visual and bidigital palpation to examine signs observed by clinician in the oral cavity e.g.:

- Missing or supernumerary teeth.
- Gingival condition.
- Soft tissue lesions, palate, tongue, buccal mucosa.
- Hard tissue condition.
- Floor of the mouth, any swellings/ bony exostosis.
- Alveolar mucosa, occlusal contact.
- Salivary glands duct stoma.
- Draining sinuses, ulcers and pigmentations.

[2] Examination of the tooth in question:

a) Visual test:

Using *mirror, probe, tongue blade, saliva ejector, fiberoptic light to examine:*

1- Discolored tooth /hypoplasia/ enamel loss/ cracks/ craze lines.

2- Deep carious lesion/ attrition/ cervical erosion.

3- Defective restoration/ leaky full-coverage crowns.

4- Intra-oral swelling.

5 Fistula, sinus tract.

6- Traumatic occlusion/ occlusal wear facets.

7- Fractures, anomalies (as developmental lingual groove).

b) Percussion test:

Although it does not indicate the health or the integrity of the pulp, it reveals the condition and spread of inflammation in the periodontal tissues.

- The patient should be first aware of the normal sensation by doing percussion on the contra-lateral tooth for comparison.
- When the patient reports severe pain on biting, the percussion test should be performed with digital pressure (index finger).
- Gentle tapping is done with the handle of the mirror vertically on the occlusal/incisal surface **Fig. (3)** as well as horizontally.

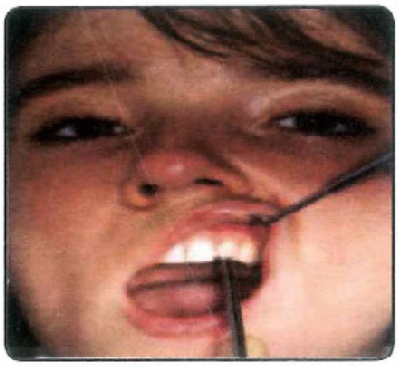


Fig. 3. Percussion test.

Positive (+ve) response to percussion could be due to:

1- Apical periodontitis as a result of:
   a- Extension of pulp inflammation.
   b- Traumatic occlusion.
   c- Over-instrumentation.
2- Acute periapical abscess.
3- Sinusitis.
4- Premature contact of high restoration.
5- Cracked tooth.

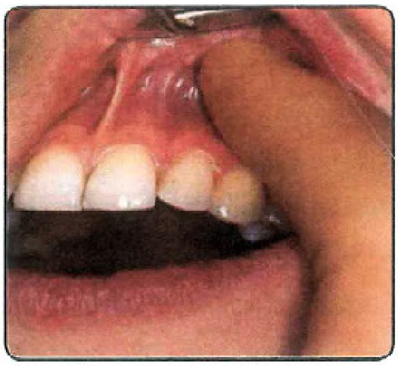


Fig. 4. Intraoral palpation

c) Palpation test:

Detection of:

- o Spread of inflammation from periapical tissues to mucoperiosteum.
- o Tenderness, location, extension and consistency

Technique:

It is performed by bilateral rolling of gloved index finger on the mucosa overlying the apices, while the mucosa is pressed against the underlying cortical bone **Fig. (4)**.

Purpose:

1- Certain clinical situations are primarily evident only during palpation (when periapical inflammation develops after pulp necrosis). Inflammatory process may burrow its way through the facial cortical plates and begins to affect overlying mucoperiosteum. This will be detected by gentle palpation before incipient swelling becomes clinically evident.
2- Detection of the intra-oral swelling and its extension.
3- Detection of consistency of a present intraoral swelling; fluctuant, indurated or provides egg-shell crackling sensation.
4- Differentiation of the normal landmarks, e.g. bony exostosis, from pathological swellings.

Example: When a mandibular tooth is abscessed, digitally palpate the submandibular area to detect whether it has been affected.

N.B.: The examination is most effective, when it is performed bilaterally.

d) Periodontal evaluation (probing):

No dental examination is complete without careful evaluation of the periodontal support and attachment level of the teeth. There is a potential communication existing between the pulp and the periodontium.

Technique: The gingival crevice is probed all around the tooth at 4 to 6 positions and tested for pocket depth if exists, plaque/ calculus, gingival/ sulcular bleeding/ drainage, or furcal involvement in multi-rooted teeth.

Besides, periodontal stability is a basic requirement for any tooth being considered for endodontic therapy which is determined by:

a- Amount of bony support.

b- Health of the bony support.

c- Health of the overlying soft tissue.

c) Mobility test:

Technique: Pressure is applied with handles of 2 instruments in a facio-lingual direction. One is placed buccally and the other lingually. Finger pressure should not be used to avoid false sensation of the soft tissue in the tip of the fingers.

Purpose: Detects the integrity of alveolar attachment and gives an idea about the periodontal status around the tooth.

Degrees of mobility:

Grade I: (less than 1 mm) physiologic, not felt by the patient or the dentist.

Grade II: (1 mm) felt by dentist and not by the patient; may require splinting.

Grade III: (more than 1 mm) felt by both dentist and the patient.

C) Diagnostic aids:

[1] Radiograph:

It is one of the most important and valuable tools to establish diagnosis, as the endodontist can visualize what he cannot see or feel during the process of diagnosis and treatment. However, we cannot rely only on the radiograph, as it has many limitations.

The following questions should guide the clinician's examination:

1- Is the lamina dura intact or there loss of lamina dura?

2- Is the bony architecture within the normal limits?

3- Is the root canal system within the normal limit or does it appear to be resorbed or calcified?

4- What anatomic landmarks could be expected in this area?

N.B.: Radiographic interpretation should be done in an organized habitual manner, so that nothing is overlooked.

1) Preoperative:

To find out if the tooth is indicated for root canal treatment and extrapolate a number of data.

- Size and level of pulp chamber.
- Number and curvature of roots and canals.
- Calcifications, stones, and resorption.
- Apical closure and apical anatomy.
- Root length and size.
- Periradicular pathosis, lamina dura and lesion extensions, alveolar bone support, periodontal membrane space.
- Previous treatments (restoration, pulp capping, pulpotomy).
- Anatomical landmarks.
- Searching for root tips and location of root apices during apicoectomy.

The presence of an extra root or root canal is much more common than was previously thought. Whenever the outline of the root is unclear or has an unusual contour, one should suspect an additional root canal; the mystery of finding an extra canal is more perplexing than the extra root itself.

Hints on how to detect the extra canal:

- By following the image of the file placed within a canal along the length of the root, if an extra dark line is apparent in the coronal third of the root, running parallel to the instrument, an extra canal should be suspected.

Example: A second mesiobuccal canal in the maxillary first molar has an incidence of 51-69%

- An abrupt, sudden change in the radiolucency of a canal probably signalizes the beginning of an additional canal and ***Shift technique*** is recommended for confirmation.

2) During operation:

1- Tooth length determination.
2- To detect any obstruction during work e.g. ledge.
3- Perforation.
4- Instrument fracture and its level.
5- Verification of the master cone.

3) Postoperative:

1- Post-treatment evaluation.
2- Follow up.

Limitations of x-ray:

1- Two-dimensional image for a three-dimensional object (mesio-distal and occluso-cervical, but not the BL). The third dimension can be obtained via an occlusal film.
2- Too long or too short image, according to the angle of the x-ray cone. Hence, no exact working length can be provided, but rather a radiographic length that needs to be adjusted and confirmed by other means.
3- It cannot identify diseases.
4- Too dark or too light image; can not determine the exact density of the bone and dentin (hard tissues).
5- In a double-curved root, it cannot determine the correct working length, so it needs a radiologist who can recognize it. These areas appear more radio-opaque, known as x-ray twice or double curved.
6- Pulp condition and soft tissue changes can not be radiographically detected.
7- Lesions of the medullar bone are likely to go undetected until resorption is considerable and has expanded and eroded a portion of the cortical plate.
8- Superimposition for which Shift technique is recommended to separate between the overlapped structures.

Common techniques of dental radiography used in endodontics:

1- Bisecting technique.
2- Paralleling technique.
3- Shift technique (Clark's rule or Buccal Object rule).

It states that the most distant object from the cone moves toward the direction of the cone.

Technique: 5° to 10° change in the horizontal angulation from the straight-on position of the cone.

Importance of Shift technique in Endodontics:

1- Tooth length determination in posterior teeth e.g. maxillary premolars and mandibular molars **Fig. (5)**.
2- Moves the anatomical landmarks, such as zygomatic process, improving the radiographic visualization of the obscured objects.
3- Distinguishes between anatomical landmarks and radiolucent shadows associated with the pathosis of the root of the teeth.
4- Distinguishes between internal & external resorption.

Recent advances in radiography:

- **Digital radiography [e.g. RadioVisioGraphy (RVG)] Fig. (6):**

It depends on a programmed computerized receiver that processes signals from an intra-oral sensor that is stimulated by X-ray from a standard machine.

The computer-enhanced signal then appears immediately on the video monitor as an image.

This image may then be varied in:

1- Size (zoom for enlargement).
2- Contrast
3- Finally, it can be printed out or stored in the computer for recall.

Digital image requires:

1- Electronic sensor or detector.
2- An analogue-to-digital converter.
3- Computer.
4- Monitor or printer for the image display.

Advantages:

1- The radiographic image is obtained immediately.
2- Elimination of x-ray film processing.
3- Radiation exposure is reduced by about 50%- 90% than the conventional film- based radiography.

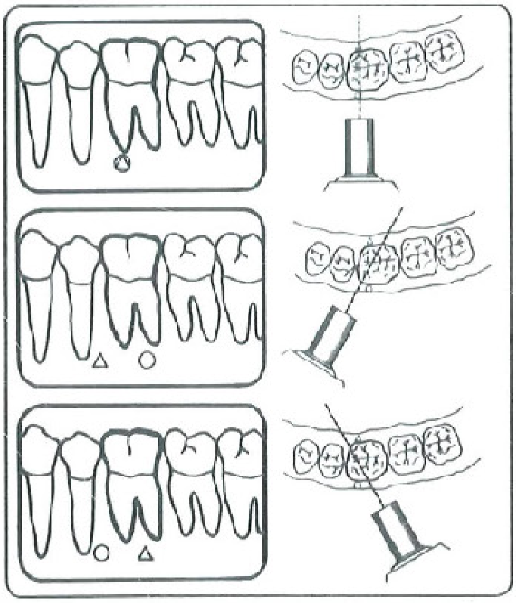


Fig 5. Horizontal shift technique to separate superimposed canals on radiograph.

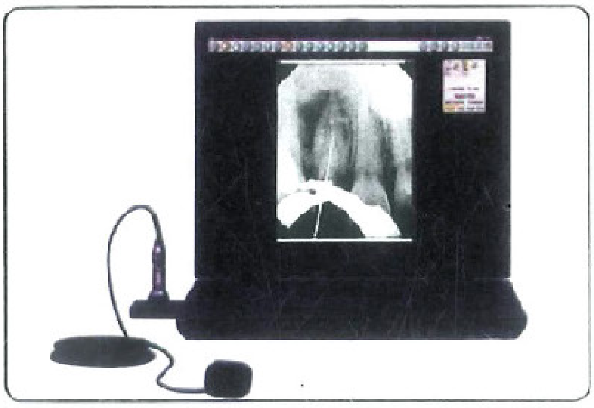


Fig. 6. Radiovisiography.

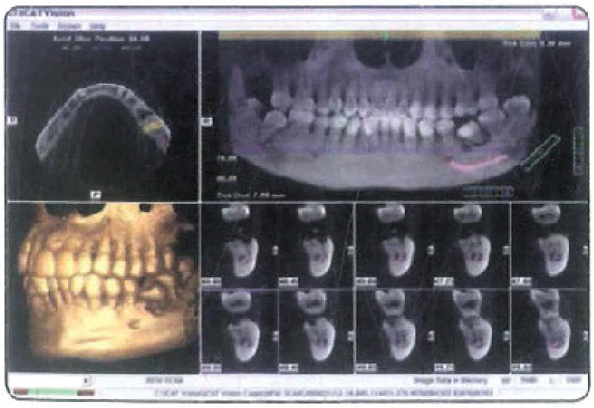


Fig. 7. CBCT software.

Disadvantages:

1 Potential reduction in the image quality when compared to conventional radiography

2- High cost.

- **Cone-Beam Computed Tomography (CBCT) Fig. (7):**

Until about 10 years ago, routine radiography consisted of only two-dimensional imaging with limitations encouraging the need for three-dimensional imaging, known as cone-beam computed tomography (CBCT) or cone-beam volumetric imaging (CBVI).

Most of these machines are similar to a dental panoramic device, whereby the patient is exposed to a cone-shaped radiographic beam directed to the target area with a reciprocating capturing sensor on the opposite side. The resulting information is digitally reconstructed and interpreted to create interface whereby the clinician can three-dimensionally interpret "slices" of the patient's tissues in several planes

[2] Pulp sensitivity tests:

These tests are based on stimulating the pulp sensory nerve fibers by either a thermal or an electrical stimulus and analyzing the response. According to the type of stimulus, tests are:

a- Thermal test (Thermometric evaluation).

b- Electric pulp test (Electrometric evaluation).

a) Thermal tests:

Thermal tests are especially valuable diagnostic aids, because, in certain types of inflamed pulps, pain may be induced or relieved by applying cold or warm stimuli.

The idea of thermal tests depends on the thermal tolerance zone of dentin, which is from 20° to 50°C, so dentin isolates any change in temperature within this range.

Before proceeding:

1- The procedure of the thermal test should be explained to the patient.

2- Demonstrate the test on several teeth or the contra-lateral tooth for comparison.

3- The clinician and the patient should agree on the signals at which the patient can indicate immediately the feeling of pain.

4- Tooth should be isolated and dried by 2 x 2-inch gauze.

5 The stimulus is applied on the middle or incisal thirds of labial surface of tooth or on the occlusal surface.

Cold test:

Cold test is more reliable in the differentiation between reversible and irreversible pulpitis than in the differentiation between vital and necrotic pulp. Teeth with calcified pulp space may be vital, but cold may not be able to excite the nerve endings.

Cold test can be made with:

1- Air blast.

2 Cold water bath.

3- Ice stick (seldom used, because they may be warm when applied to the teeth and fall onto the gingival giving a false + ve response).

4- Ethyl chloride (-53°F) **Fig. (9).**

5- Flori-methane sprays (-21°F).

6- Carbon dioxide (CO_2) dry stick (-77°or 108°F) excessive cold may cause infraction lines in enamel or damage the healthy pulp.

Rickoff reported that CO_2 snow applied to the tooth for 5 minutes did not jeopardize the health of the pulp nor damage the surface of enamel. On the other hand, it causes pitting of porcelain crowns.

Hot test:

Can be more reliable to differentiate between vital and necrotic pulp.

Hot test is performed using:

1- Gutta-percha stopping (gutta-percha is warmed, formed into a cone, applied to the instrument, reheated and applied to the teeth).

2- Rotating a dry prophy cup to create frictional heat.

3- Hot water bath **Fig. (8)**.

Fig. 8. Water bath.

Fig. 9. Cold test.

N.B.: Cold or hot water bath, though time consuming, is the most accurate method because:

1- Use of water allows the entire crown to be immersed and not just one section of the tooth.

2- Cold or hot water bath prevents excessive temperature damage to the tooth.

3- Allows simulation of clinical situation.

***Response to thermal tests:* (*4* possible responses)**

1- Mild-to-moderate degree of awareness of slight pain that subsides within 1-2 seconds after removal of the stimulus (normal limits).

2- Strong, momentary, painful response that subsides within 1-2 seconds after the stimulus has been removed (reversible pulpitis).

3- Moderate-to-strong, painful response that lingers for some seconds/ minutes after the stimulus has been removed (irreversible pulpitis).

4- No response, indicates necrotic pulp, recent trauma or excessive calcification.

b) Electric pulp test (EPT):

1- It detects the sensitivity of the pulp by stimulating a response of the pulpal sensory nerve fibers using an electric current, which must first pass through a resistant layer of enamel Fig. (10).

2- The +ve response means that there are neural elements (sensory nerves) in the pulp. However, it does not mean that the pulp is totally intact, because the neural elements in the pulp are the last to degenerate.

3- EPT does not provide any information about the vascular supply of the pulp, which is a true determination of the pulp vitality.

<u>*N.B.:*</u> EPT should not be used on a patient with a cardiac pacemaker for fear of arrhythmia.

Variables that can influence pulp testing:

1- Age.

2- Mental and emotional stress.

3- Drug influence.

4- Pain threshold level of the patient.

5- Condition of the teeth.

Technique:

1- Siemen's EPT:

Two electrodes, the patient holds one in his hand and another on the tooth, are used and the voltage is increased then the patient is asked about his sensation. The problem is that the patient can become afraid that the electrode in his hand may give him an electric shock, so many leave it to fall giving a false reading.

2- Monopode EPT:

- Attached to unit.
- The same as before, but you do not have to complete the circuit with the patient.

3- Battery-operated EPT:

As the previous one, but has its own battery for power. One of its limitations is that when the battery is off, there is no way to know and it will give a false reading, so the battery must be checked daily.

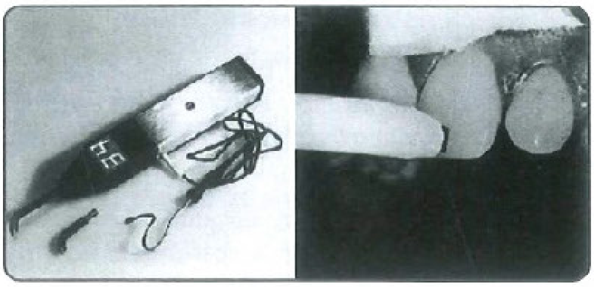


Fig. 10. Electric pulp tester.

Limitations of EPT:

Although it is a valuable diagnostic aid, it is not reliable. It provides information that must be confirmed by other tests.

1) False -ve:

1- Recently-erupted tooth: Up to 12 years, due to the neural element, which is a highly-specialized tissue and the last to mature.

2- Recently-traumatized tooth: The tooth is in a state of shock. Edema causes pressure on the nerve endings giving no response. Test should be repeated after 15 - 30 days.

3- Diffuse pulp calcification.

4- Presence of reparative dentine.

5- Inadequate contact between the electrode and enamel.

2) False +ve:

1- In case of multirooted teeth, where one root canal has necrosed and the other has vital pulp.

2- Liquifactive necrosis; it is not vital, but can result in +ve response because of eletrolytes.

3- Tooth is not dry (thin film of saliva).

4- Gingival response due to the wrong position of the tip.

5- Electrode placed near a large metallic restoration.

6- Anxiety.

Recent advances for vitality testing:

Vitality tests: They test the vascular element and the blood circulation of the pulp tissue.

a) **Laser Doppler Flowmetry (LDF):**

- Measures the pulpal blood flow and, thus, the degree of vitality. The ability to measure pulpal blood flow using LDF was first shown in 1986.
- This was followed by a demonstration that LDF was capable of assessing the vitality of the tooth and re-vascularisation of traumatized tooth.
- The equipment used is a laser diode emitting light. This instrument uses a probe that is held on the buccal surface of the tooth during measurement **Fig. (11)**.

This probe has three fibers:

- One fiber carrying laser light to the pulp tissue.
- Two fibers carrying the back-scattered light to a detector, giving output signals **Fig. (12)**.

Traus et al. found that signals were 42.7% lower in necrotic teeth than in vital teeth.

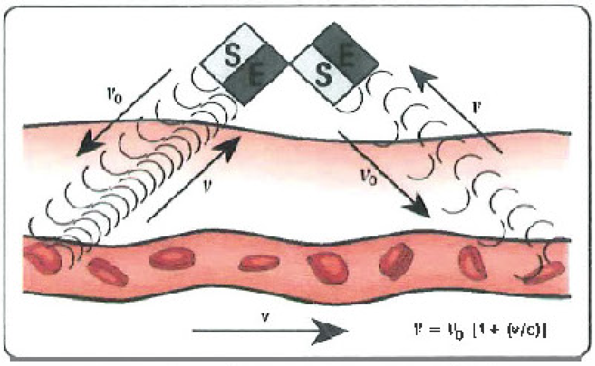


Fig. 11. Laser Doppler Flowmetry (LDF).

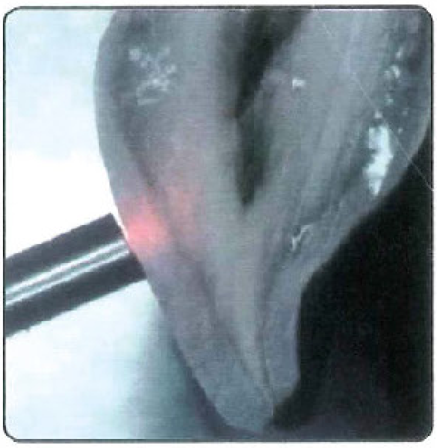


Fig. 12. Mechanism of action of LDF.

Advantages:

- High accuracy
- Can be used with:
  - Anxious patients.
  - Mentally-retarded patients.
  - Very young patients.
  - Unconscious patients.

Disadvantage:

Too complex and time consuming for the general dental practitioners' clinic.

b) **Pulse Oximetry:**

- Records oxygenation of the pulpal blood flow.
- The Pulse Oximeter **Fig. (13)** has emerged as the non-invasive monitoring device for determining the oxygen saturation and the pulse rate of patients under intensive care or during sedation procedure.
- The principle is simple in that light (red and infrared wavelengths) is passed from photoelectric diode across a part of the body and into a receptor.

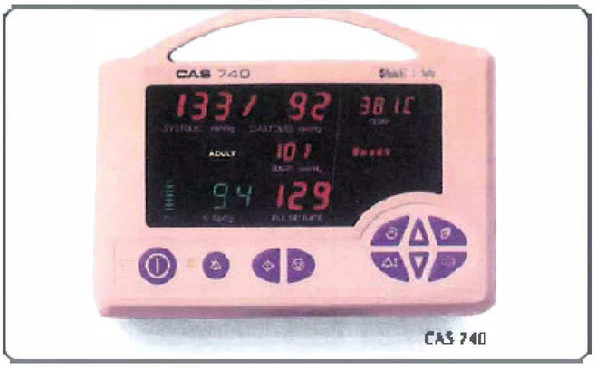


Fig. 13. Pulse Oximeter.

- The difference between the light emitted and the light received is calculated in a microprocessor to provide pulse rate and oxygen saturation reading.
- Two wavelengths of light are emitted from the diode to detect oxygenated hemoglobin

(Hb) (arterial blood) and de-oxygenated Hb (venous blood). It is the ratio of absorbency of wavelength that provides the percentage of oxygenation of the blood.

- Although all these methods are successfully applied in medicine and in dental researches, they have been less successfully applied to routine endodontics due to the fact that the circulating system of the pulp is enclosed within a rigid structure, therefore, it is difficult to study without extensive tissue removal.

c) Liquid crystal testing (cholesteric liquid crystal)

Cholesteric liquid crystals have been used by several investigators to show the difference in tooth temperature between a vital (hotter) pulp and necrotic (cooler) pulp.

d) Hughes Probeye camera:

It is capable of detecting temporary changes in temperature as small as 0.1°C; thus, experimentally measuring pulp vitality.

[3] Selective tests for difficult clinical situations:

a) Occlusal pressure test (Biting test):

Pain on biting could be due to:

- Apical periodontitis.
- Apical abscess.
- Incomplete tooth fracture/ cracked tooth.

Clinical test simulating the chief complaint in the occlusal pressure test includes:

Wedging force applied by biting on:

1- Orange wood sticks
2- Rubber disc.
3- Wet cotton roll.
4- Tooth slooth **Fig. (14)**.

All these items have the ability to simulate the bolus of food and apply pressure on the occlusal surface to detect crown fracture as well as cuspal shear fractures.

Tooth slooth allows pinpoint testing of each individual cusp. Wet cotton rolls have the advantage of adapting to the occlusal surface, allowing pressure over the entire occlusal table.

Application of a stain (mythelene blue) before biting on cotton or wood stick, followed by cleaning with 70% alcohol results in exhibiting the fracture lines clearly stained **Fig. (15)**.

b) Trans-illumination test:

Technique: In dim light, fiberoptic light is applied to one surface of the tooth then the dentist examines the tooth from the other side **Fig. (16)**.

To detect: Internal resorption, cracks or proximal decay.

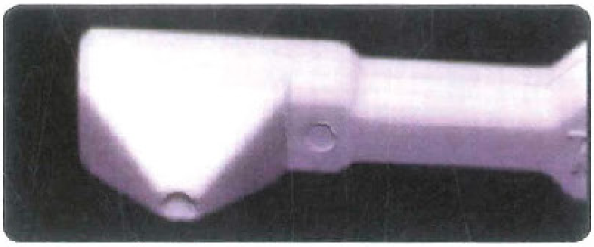


Fig. 14. Tooth Slooth

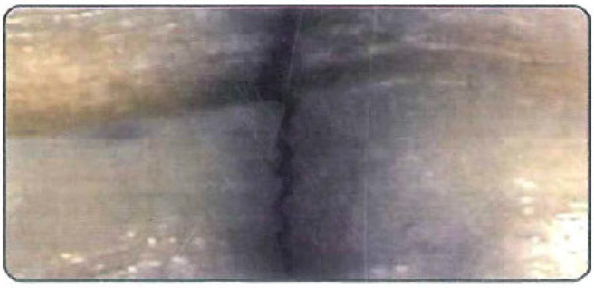


Fig. 15. Dye test.

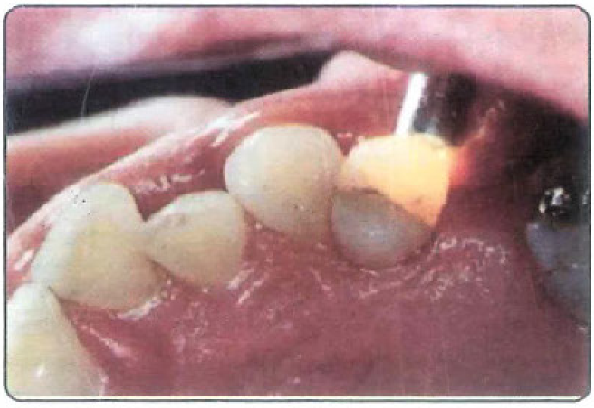


Fig. 16. Trans-illumination test.

c) **Anesthesia test:**

To determine the exact tooth responsible for the aching pain acting as its primary source while it is being referred to the opposite arch or the adjacent tooth. This is achieved by intraligamentary injection of the tested tooth with 0.2 ml of local anesthesia.

d) **Gutta percha point tracing with radiograph:**

Technique: Place a gutta-percha point through a fistulous tract and take a radiograph **Fig. (17)**.

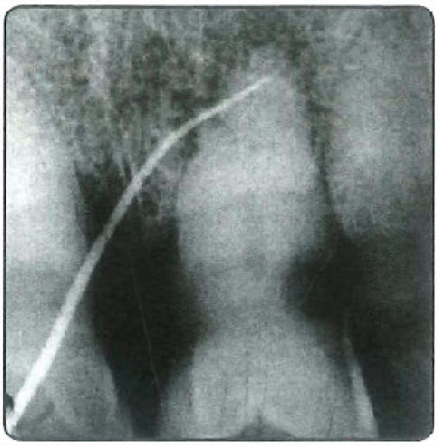


Fig. 17. Gutta-percha tracing.

Purpose:

i- Relating the endodontic lesion to the diseased tooth.

ii- Differentiate periodontal lesion from endodontic lesion.

e) **Cavity test:**

In case of extensive composite resin restoration or a ceramic crown, a small class I preparation is made through the crown with a round bur so that when it touches the dentine, a response is received from the vital tooth.

III. Laboratory Investigations:

Laboratory investigation could be recommended in case of suspicion as blood glucose level, bleeding time, clotting time, kidney function test and level function test ... etc.

Recent advances in endodontic diagnosis

- **Dental operating microscope (DOM):**

Being used in medicine for years, the Dental Operating Microscope (DOM) has represented the evolving art and science in endodontics since its introduction in 1992 by Dr. Gary Carr. It has become an extremely valuable tool when performing endodontic diagnosis as well as during treatment (Fig 18-20).

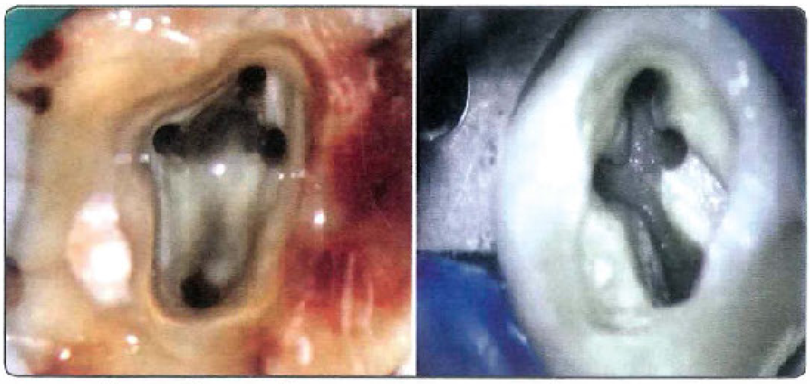


Fig. 18. Hidden orifices and extra second mesio-buccal canals detected by DOM in maxillary first molars.

Fig. 19. Diagnosis of cracked tooth syndrome.

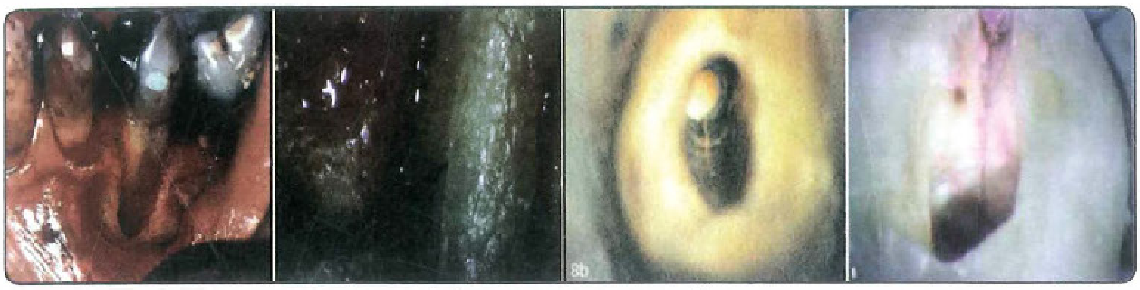


Fig. 20. Diagnosis of vertical root fractures.

CHAPTER REVIEW QUESTIONS

1. Define endodontic diagnosis, and mention its main routes.
2. Discuss the importance of accurate medical history taking.
3. Discuss the importance and procedures of the present dental history (chief complaint).
4. Mention the main steps of clinical examination with emphasis on intraoral examination.
5. Discuss the different diagnostic aids of importance to endodontic diagnosis.
6. Discuss the importance and limitations of endodontic radiography.
7. Discuss the recent advances in endodontic radiography.
8. Discuss the importance and limitations and recent advances in pulp vitality testing.

REFERENCES

- Hargreaves KM, Cohen S. Cohen's Pathways of the Pulp. 10th ed. Mosby El Sevier, 2011.
- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics. 6th ed. BC Decker Inc.,2008.
- Walton RE, Torabinejad M. Principles and Practice of Endodontics. 4th ed W.B. Saunders company, 2009.
- Bender IB: Pulpal pain diagnosis: a review. J Endod 26:175, 2000.
- Karayilmaz H, Kirzioglu Z. Comparison of the reliability of laser Doppler flowmetry, pulse oximetry and electric pulp tester in assessing the pulp vitality of human teeth. J Oral Rehabil 38:340, 2011.
- Abella F, Patel S, Duran-Sindreu F, Mercadé M, Bueno R, Roig M. Evaluating the periapical status of teeth with irreversible pulpitis by using cone-beam computed tomography scanning and periapical radiographs. J Endod 38:1588, 2012.

3

Structure and Function of The Dentin-Pulp Complex

Abeer A. Saba

Intended Learning objectives

After reading this chapter, the student should be able to

1. Understand causes of uniqueness of the dental pulp.
2. List functions of dental pulp.
3. Recognize correlation between dentin and dental pulp.
4. Identify different types of dentin.
5. Describe different morphological zones of the pulp.
6. Identify different cells of the pulp.
7. Identify extracellular elements of the pulp.
8. Identify pulp interstitium and ground substance.
9. Identify supportive elements of the pulp.
10. Correlates regulation of pulpal blood flow with circulation in the inflamed pulp.
11. Correlates pulp innervations with pulp testing techniques and types of pulpitis.
12. Recognize age changes in the dental pulp.

Chapter Outline

Functions of dental pulp
The dentin-pulp complex
Dentin Structure
Primary (developmental) dentin
Mantle dentin
Circumpulpal dentin
Predentin
Dentinal tubules
Intertubular dentin
Intratubular (Peritubular) dentin
Secondary (physiologic) dentin
Tertiary dentin
Dentinal sclerosis
Pulp Structure
Morphologic zones of the pulp
Odontoblast Layer (peripheral zone)
Cell-Poor Zone (cell-free layer of Weil)
Cell-Rich zone
Pulp Proper (central zone)
Cellular elements of the pulp
Progenitor Cells/ Undifferentiated Mesenchymal Stem Cells (UMCs)
Formative cells.
- *Odontoblasts*
- *Fibroblasts*

Defensive Cells:
- *Macrophages*
- *Dendritic Cells*
- *Lymphocytes*
- *Mast cells*
- *Additional defensive cells found only in inflamed pulps*
  - *Polymorph Nuclear Leukocyte*
  - *Plasma cells*

Extracellular elements of the pulp
Pulp interstitium and ground substance
Ground Substance
Connective Tissue Fibers
Supportive elements of the pulp
Blood supply
- *Regulation of pulpal blood flow*

Nerve supply
- *Motor nerves (Sympathetic)*
- *Sensory nerves (Afferent)*
- *Neuropeptides*

Age changes in the pulp

Dental pulp is a *unique* non-mineralized soft connective tissue that occupies the central pulp cavity of each tooth.

The *uniqueness* of the pulp is attributed to:

- Pulp is completely surrounded by rigid mineralized dentin which limits its ability to expand during episodes of vasodilatation accompanied with inflammation.
- Pulp lacks collateral system and few arterioles entering through the apical foramen.
- Pulp has the ability to form dentin throughout life.
- Pulp consists primarily of sensory fibers which enables it to function as exquisitely responsive sensory system despite its confinement by enamel and dentin.

Functions of the Dental Pulp:

1. **Inductive:** very early in development, the dental papilla (the future pulp) interacts with the oral epithelial cells, leading to differentiation of dental lamina and enamel organ formation and initiates tooth formation.
2. **Formative:** involved in the support, maintenance and continued formation of dentin.
3. **Nutritive:** maintains dentine vitality by providing oxygen and nutrients to the odontoblasts.
4. **Protective:** development and formation of secondary and tertiary dentin which increase the coverage of the pulp.
5. **Defensive:** triggering of inflammatory and immune response. Pulp helps in recognition of stimuli like heat, cold, pressure or chemicals by its sensory nerve fibers. The vasomotor innervations controls the muscular wall of blood vessels which regulate blood volume and rate of blood flow and hence intrapulpal pressure.
6. **Sensory:** its rich innervation alerts the individual when injury occurs to dentin and pulp.

The dentin-pulp complex

The dentin and pulp function as a unit; they are related to each other:

1. ***Embryologically:*** Both are derived from ectomesenchymal cells of the dental papilla.
2. ***Anatomically:*** Tome's fibers constituting third of the dentin structure, are protoplasmic processes of odontoblasts which are cells of the pulp.
3. ***Physiologically:*** Dentin provides thermal protection to the pulp, while pulp provides nutrition to dentin.

Dentin Structure

Highly mineralized connective tissue consisting of:

- 70% inorganic material (Calcium hydroxyapatite).
- 20% organic material (about 91% collagen; mainly type I and minor component of type V, and non-collagenous proteins).
- 10% water.
- **Types** (Fig. 1):
    1. **Primary (developmental) dentin:** Is the dentin formed in a tooth before the completion of the apical foramen of the root. It is noted for its regular pattern of tubules.
    2. **Mantle dentin:** Is the outer, first mineralized layer of primary dentin formed and is produced by odontoblasts that are not yet fully differentiated and situated immediately adjacent to the enamel or cementum. Mantle dentin can be recognized by the characteristic thick, fan-shaped collagen fibers. It is also slightly less mineralized than underlying dentin.

3. **Circumpulpal dentin:** Is formed after the layer of mantle dentin has been formed and constitutes the major part of developmental dentin.

4. **Predentin:** Is un-mineralized organic matrix layer of dentin and situated between the odontoblastic layer and the mineralized dentin. The collagen fibers of predentin undergo mineralization at the predentin-dentin front; the predentin then becomes dentin and a new layer of predentin forms circumpulpally.

5. **Dentinal tubules:** A characteristic of human dentin is the presence of tubules that occupy from 1% (superficial dentin) to 30% (deep dentin). The dentinal tubules slightly taper with wider portion situated toward the pulp. In coronal dentin, the tubules have a gentle S-shape as they extend from DEJ to the pulp. This results in crowding of odontoblasts as they migrate toward center of the pulp. Near the DEJ, the dentinal tubules ramify into one or more terminal branches.

6. **Intertubular dentin:** Is the dentin found between the dentinal tubules and constitutes the bulk of dentin.

7. **Intratubular (Peritubular) dentin:** Is the dentin lining the inner walls of the dentinal tubules. It differs from intertubular dentin by having relatively fewer collagen fibrils and higher mineral content making it harder and more quickly dissolved in acid by acid-etching agents.

8. **Secondary (physiologic) dentin:** Is the dentin that is formed after the completion of the apical foramen and formed throughout the life of the tooth.

9. **Tertiary dentin:** Is the dentin that is formed as a result of pathologic stimulus such as caries or occlusal abrasion to protect the pulp from noxious stimulus and subdivided into:

   a) **Reactionary dentin:** secreted by the original odontoblasts in which the dentinal tubules within, are continuous with those of primary and secondary dentin.

   b) **Reparative dentin:** secreted in case of death of original odontoblasts by odontoblast like cells which differentiate from mesenchymal stem cells present in the pulp. There is no continuity between dentinal tubules of reparative dentin and overlying primary and secondary dentin.

10. **Dentinal sclerosis:** Partial or complete obliteration of dentinal tubules may occur as a result of aging or develop in response to persistent stimuli such as attrition or dental caries. Gradually, the tubule lumen is filled with mineral deposits that may help to prolong pulp vitality and reduce dentin permeability. Dentinal scelerosis is easily recognized in histologic ground sections because of its translucency (due to homogeneity of the dentin).

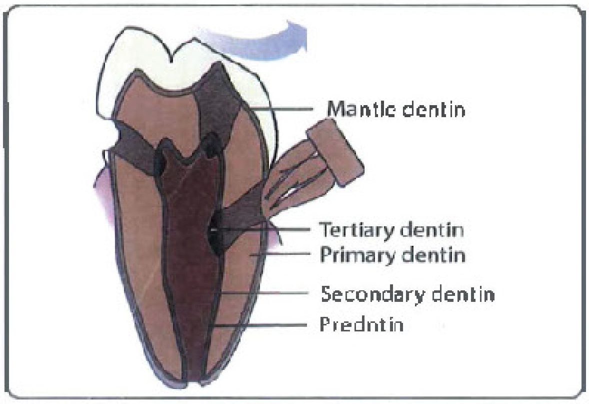


Fig. 1 Diagram illustrating different types of dentin.

Pulp Structure:

Morphologic zones of the pulp (Fig. 2-3):

1. **Odontoblast Layer (peripheral zone):**
   - The outermost layer of the pulp and located immediately subjacent to the Predentin and passes through the Predentin into the dentin.

- It is composed of the cell bodies of the ododntoblasts in addition to capillaries, nerve fibers and dendritic cells among the odontoblasts.
- The odontoblast layer in the coronal pulp contains more cells per unit area than in the radicular pulp, so the odontoblasts cells spread out laterally in radicular pulp.

2. **Cell-Poor Zone (cell-free layer of Weil):**
   - Immediately subjacent to the odontoblast layer.
   - 40 µ in width and relatively free of cells.
   - It is traversed by blood vessels, unmyelinated nerve fibers and cytoplasmic processes of fibroblasts.
   - Relatively diminished in young age (dentin forms rapidly) and older pulps (reparative dentine formation).

3. **Cell-Rich zone:**
   - It is the layer subjacent to cell poor zone.
   - It is more prominent in the coronal pulp than in the radicular pulp.
   - Contains fibroblasts, macrophages, lymphocytes, dendritic cells and undifferentiated mesenchymal stem cells (UMC).
   - It is formed as a result of migration of cells from pulp proper.
   - Mitosis is seen when dead odontoblasts are replaced.

4. **Pulp Proper (central zone):**
   - It is the central mass of the pulp.
   - Consists of loose connective tissue and contains the larger blood vessels and nerves.
   - Fibroblast is the most prominent cell in this zone.

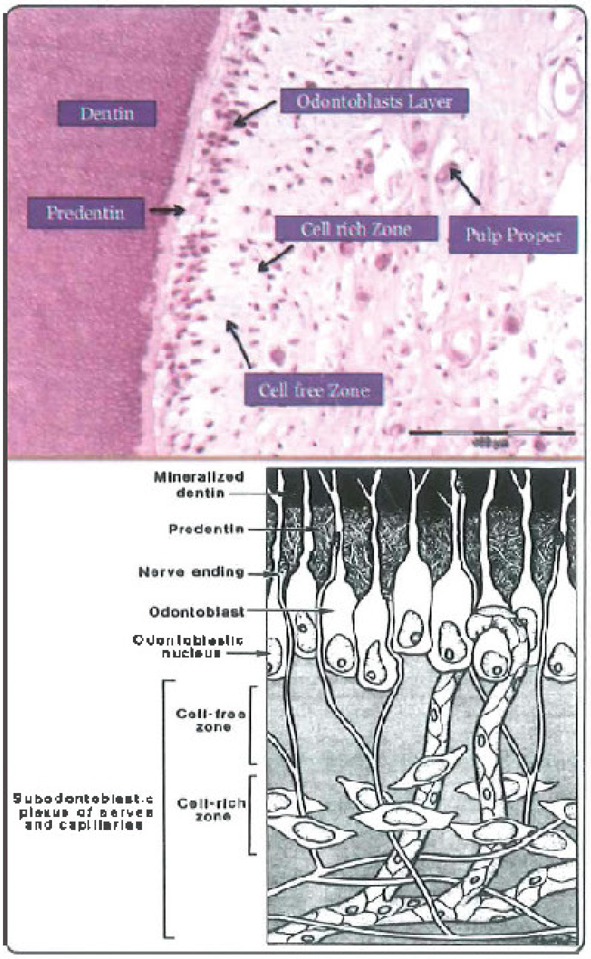


Fig. 2-3 Morphologic zones of mature pulp.

Structural Elements of the Pulp

The dental pulp is a connective tissue, like other connective tissues in the body; it consists of:

Cellular Elements, Extracellular Elements and Supportive Elements.

I) Cellular Elements of the Pulp:

A. <u>Progenitor Cells/ Undifferentiated Mesenchymal Stem Cells (UMCs)</u>

- Stem cells are the body's *master* cells that regenerate the body's many cells, tissues and organs.
- The most commonly known source of adult stem cells is bone marrow, which

contains both hematopoietic stem cells (forms all types of blood cells) and mesenchymal stem cells (also found in teeth).

- UMCs in the pulp are usually found along the walls of the blood vessels and in cell-rich zone.
- They are multipotent cells which can differentiate under adequate stimulus (i.e transforming growth factors and bone morphogenic proteins) into other mature cell types (odontoblast, fibroblast or macrophage) according to the need,

  i.e. they may differentiate into:

  - Odontoblasts ... in case of odontoblasts injury or death.
  - Odontoblast-like cells ... that form calcified tissue under the pulp capping or pulpotomies.
  - Odontoclasts ... responsible for internal resorption.
- They are smaller than fibroblasts but have a similar appearance.
- In older pulp, their number and ability to differentiate decreases.
- Recently, have been used in regeneration of pulp in immature teeth.

B. <u>Formative cells.</u>

1) Odontoblasts (Fig. 4):

- They line the pulpal surface of dentin and separated from dentin by a layer of predentin.
- The number of odontoblasts corresponds to the number of dentinal tubules (average of 59.000- 76.000 odontoblasts per Sq.mm in coronal dentin, less in root dentin).
- Each odontoblast has a cell body (perikaryon) and one odontoblastic process (Tomes fiber) that runs inside the dentinal tubule.
- The odontoblastic process extend from the cell body to the inner 1/3 of dentin, with the outer 2/3 of the dentinal tubule is devoid of processes or of nerves but filled with extra-cellular fluid.
- Shape:
  - In pulp chamber ... pseudostratified columnar
  - Coronal portion of root ... tall columnar
  - Mid portion of root ... cuboidal
  - Near apical foramen ... flattened
- The odontoblasts are arranged in a single layer, yet in coronal pulp, odontoblasts vary in height and their nuclei are not all at the same level giving a palisade appearance which makes the layer appears to be three to five cells in thickness even though there is only one actual layer of odontoblasts.
- Numerous junctions such as gap junctions, tight junctions and desmosomes are found between odontoblasts, promoting cell to cell adhesion and indicating exchange of ions and small molecules.
- Function of odontoblasts:

1) Secretory role:

The principle cell in dentinogenesis responsible for synthesis of organic matrix through secreting:

a. Collagen type I and fewer of type V

b. Non-collagenous elements including:

- Proteoglycans ... synthesis of organic matrix.
- Phosphophoryn ... for extracellular mineralization.
- Alkaline phosphatase ... for mineralization.
- Acid phosphatase ... degradation of organic matrix

2) Defensive role:

- Formation of reparative, peritubular or sclerotic dentin.

3) Intracellular accumulation of calcium

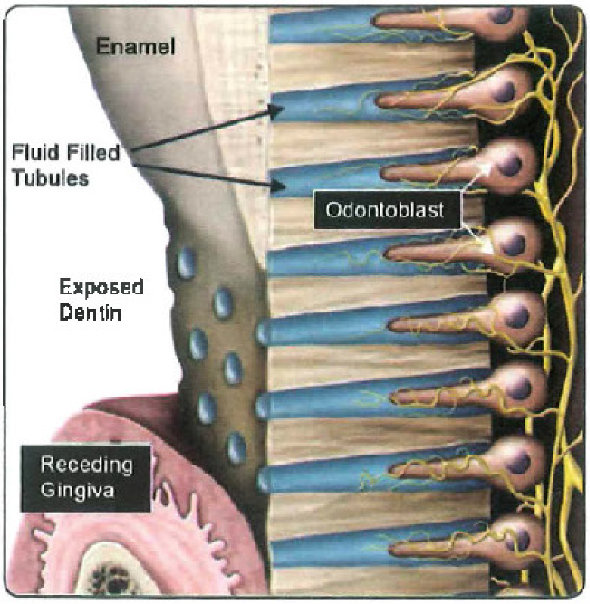


Fig. 4. Diagram illustrating odontoblasts.

2) Fibroblasts (Fig. 5):

- They are the most numerous cells of the pulp, particularly in the cell-rich zone.
- They are star like cells with ovoid nucleus.
- Function:
  - Form and maintain the pulp matrix through synthesis of collagen types I and III and proteoglycans.
  - Responsible for collagen turnover in the pulp (capable to phagocytose and digest collagen).

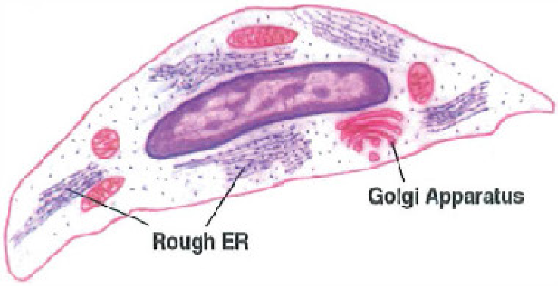


Fig. 5. Diagram illustrating fibroblast cell.

C. Defensive Cells:

1) Macrophages (Fig. 6):

- They are monocytes that have left the bloodstream, entered the tissues and differentiated into various subpopulations (described as histiocytes or resting wandering cells)
- Located close to the blood vessels
- Have phagocytic activity enabling them to act as scavengers; removing extravasated red blood cells, dead cells and foreign bodies.
- The ingested material is destroyed by the action of their lysosomal enzymes.

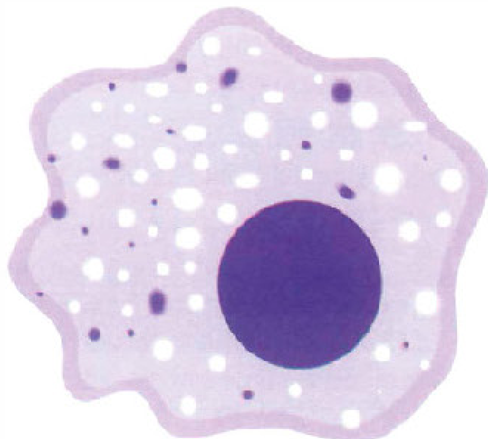


Fig. 6. Diagram illustrating macrophage cell.

2) Dendritic Cell (Fig 7):

- Bone marrow derived, antigen-presenting cells.
- Mostly located in the periphery of the coronal pulp close to the predentin, but migrate centrally in the pulp after antigenic challenge.
- They capture and present foreign antigen to T-cells.

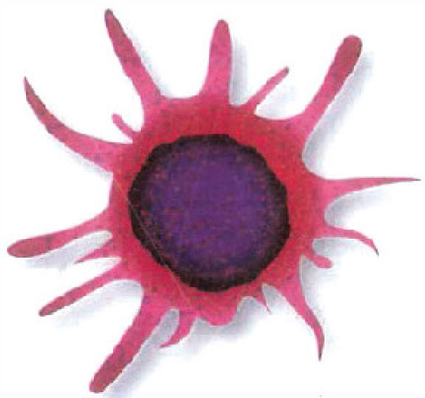


Fig. 7 Diagram illustrating dendritic cell.

3) Lymphocyte (Fig. 8):

- T-lymphocytes are present in normal pulp while B-lymphocytes are scarcely found in normal pulp.
- Mostly located along the walls of the blood vessels.

Fig. 8 Diagram illustrating T-lymphocyte cell.

4) Mast cell (Fig. 9):

- Seldom found in healthy pulps as small groups near blood vessels but, commonly found in chronic inflamed pulps.
- During inflammation, they degranulate releasing heparin (anticoagulant) and histamine (inflammatory mediator) into the surrounding tissue fluid resulting in vasodilatation and increase vessels permeability.

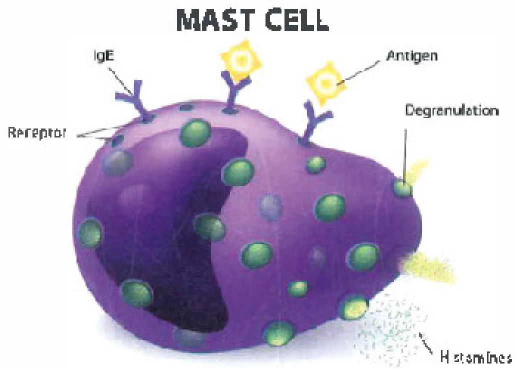


Fig. 9 Diagram illustrating mast cell

5) Additional defensive cells found only in inflamed pulps

- **Polymorph Nuclear Leukocyte** (Fig. 10):

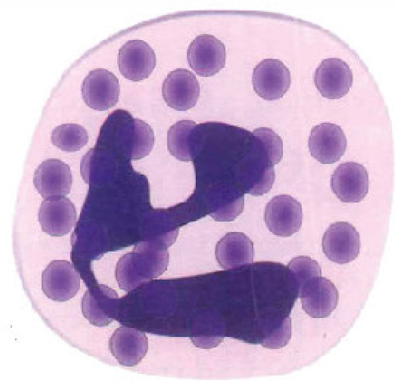


Fig. 10 Diagram illustrating polymorph nuclear leukocyte cell.

- Absent in normal healthy pulp.
- The most common form of leukocyte in acute inflammation, rapidly migrate from nearby vessels.

- Very effective in destroying and phagocyting bacteria or dead cells but often cause injury to adjacent cells leading to wider zones of inflammation and microabcess formation.

– **Plasma cells** (Fig 11):

- Absent in normal healthy pulp.
- Appear following invasion into the area of injury by Polymorph Nuclear Leukocyte, so their presence indicate persistent irritant and tissue injury (chronic inflammation).
- Also known to produce antibodies.

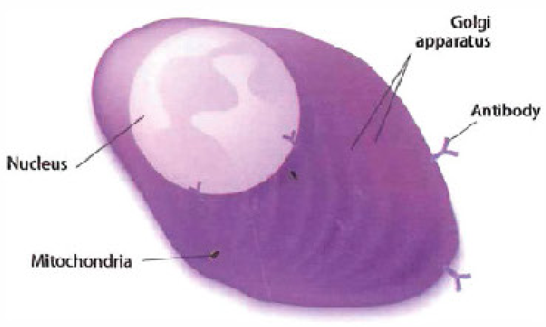


Fig. 11 Diagram illustrating plasma cell.

II) Extracellular Elements of the Pulp

Pulp Interstitium and Ground Substance

The interstitium consists of the interstitial fluid and the extracellular matrix and occupies the extracellular and extravascular spaces.

The extracellular matrix (ECM) consists of ground substance and connective tissue fibers.

A) Ground Substance

- It is amorphous (structureless) mass, gel like in consistency, makes up the bulk of the pulp organ.
- Composed mainly of proteins, carbohydrates and water.
- *Function:*

a) Supports and surrounds pulp tissue cells.

b) Forms a cushion capable of protecting cells and vascular components of the tooth.

c) Acts as a molecular sieve, it excludes large proteins. While cell metabolites, nutrients, and wastes pass through the ground substance between cells and blood vessels.

- *Composition:*
- Nearly all proteins of the ECM are Proteoglycans which are an important subclass of Glycoproteins.
- These molecules support pulp cells and mediate a variety of cell interactions.
- They have in common the presence of GAG chains (Glycosaminoglycans) and a protein core to which these chains are linked.
- The primary function of GAG chains is to act as adhesive molecules that can bond to cell surfaces and other matrix molecules.
- In the pulp, the principal Proteoglycans include:
    a) Hyaluronic acid.
    b) Dermatan sulfate.
    c) Chondroitin sulfate.
- During active dentinogenesis, *Chondroitin sulfate* is the principal Proteoglycan, particularly in the odontoblast and predentin layer, where it is somehow involved with mineralization.
- With tooth eruption, *Hyaluronic acid* and *Dermatan sulfate* increase, and *Chondroitin sulfate* decreases greatly.
- The Proteoglycan content of pulp tissue decreases approximately 50% with tooth eruption.
- Degradation of ground substance can occur in certain inflammatory lesions that have a high concentration of macrophage lysosomal enzymes.

B) Connective Tissue Fibers

- Two types of fibers are found: collagen and elastin.

a) ***Elastin fibers*** ® are confined to the walls of blood vessels.

b) ***Collagen fibers*** ®are the major structural component of ECM.

- A single collagen molecule, referred to as *tropocollagen*, consists of three polypeptide chains, designated as either alpha-1 or alpha-2 depending on their amino acid composition and sequence. The different combinations and linkages of chains making up the tropocollagen molecule have allowed collagen fibers to be classified into a number of types.
- Type I and type III collagen represent the major subtypes of collagen in the pulp.
- Type I collagen is synthesized by odontoblasts, while type III is synthesized by fibroblasts.
- However, the type of collagen produced by odontoblasts to subsequently mineralize differs from the collagen produced by fibroblasts that normally doesn't calcify.
- Collagen fibers are scattered throughout the pulp or appear in bundles. Collagen bundles are much more numerous in the radicular pulp than in the coronal pulp with highest concentration found near the apex.
- Collagen bundles passing from the dentin matrix between odontoblasts into the pulp periphery are termed Von Korffs fibers.
- *Function:*

a) Collagen fibers have great tensile strength giving the tissue consistency and strength.

b) The network of collagen fibers also supports other structural elements of the pulp.

III) Supportive Elements of the Pulp (Fig. 12) :

A) Blood supply:

- Blood supply of the pulp comes from the superior and inferior alveolar arteries to the tooth by the way of arterioles.
- Main entrance through apical foramen, but smaller vessels may enter the pulp by way of lateral or accessory canals.
- In the central portion of the radicular pulp, the arterioles give off branches that spread laterally toward the odontoblast layer, to form a capillary network in the subodontoblastic region. This network provides the odontoblasts with a rich source of metabolites.
- Capillary blood flow in the coronal portion of the pulp is nearly twice that in the root portion. Where blood flow in the region of the pulp horns is greater than in all other areas of the pulp.
- Blood passes from the capillary plexus to post-capillary venules then larger venules. The collecting venules become larger as they reach to the central region of the pulp.

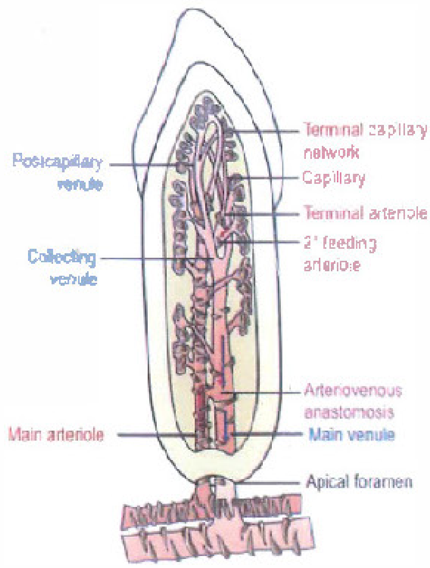


Fig. 12 Diagram illustrating vascular supply of pulp.

- Lymphatics:
  1. Historically, the existence of lymphatics in the pulp has been a matter of debate because it is difficult to distinguish between blood and lymphatic vessels by ordinary microscope. Recently, specific lymphatic markers have been applied and an extensive system of lymphatic vessels in the pulp is now recognized to exist.
  2. Lymphatic vessels form fine network near odontoblast layer and Weil's zone. Larger collecting lymphatic vessels run along the blood vessels, and exit through the apical foramen to drain filtered fluid and proteins from pulp into the periodontal ligament.
- **Transcapillary Fluid Exchange** (Fig. 13):
  a) Fluid transport between the pulpal blood vessels and the interstitial space is regulated by: lymph flow and differences in colloidal osmotic and hydrostatic pressures in the plasma and interstitium.

  b) During normal conditions, a steady state is achieved as the fluid filtered into the interstitial space equals the amount of fluid transported out.

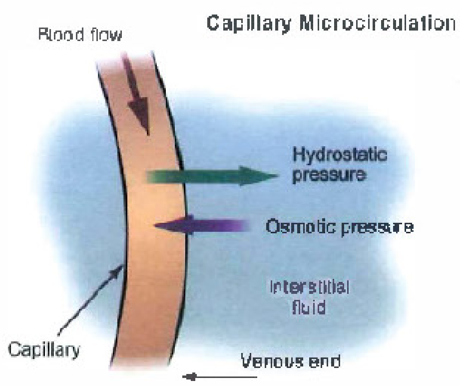


Fig. 13 Diagram illustrating Transcapillary Fluid Exchange of pulp.

- **Regulation of pulpal blood flow:**
  a) Under normal physiologic conditions, pulpal vascular tone is controlled by neuronal, paracrine, and endocrine mechanisms that keep the blood vessels in a state of partial constriction.

  b) The pulpal blood flow is also influenced by vascular tone in neighboring tissues. Vasodilatation in these tissues causes drop in pulpal blood flow due to reduction in local arterial pressure of the teeth (Stealing Theory).

  c) Inflammation in the pulp takes place in a low-compliance environment composed of rigid dentinal walls. *Compliance* is defined as the relationship between volume and interstitial pressure. The acute vascular reactions to an inflammatory stimulus are vasodilatation and increased vascular permeability, both of which will increase pulp interstitial fluid pressure and may tend to compress blood vessels and counteract the beneficial blood flow increase.

B) Nerve supply:

- Dental pulp contains both sensory and motor nerves:
- *Motor nerves (Sympathetic):*
  a) Are supplied by the sympathetic fibers of the superior cervical ganglion. In the adult pulps, sympathetic fibers form plexuses around pulp arteriole and regulate pulp microcirculation.

  b) Stimulation of these fibers results in constriction of the arterioles and a decrease in blood flow.

  c) Are most often located in deeper parts of the pulp proper, but fibers have also been found in close relation to odontoblasts.

- ***Sensory nerves (Afferent):*** (Table 1)
  a) Are supplied by sensory fibers from branches of maxillary and mandibular divisions of trigeminal nerve.
  b) The sensory nerves of the pulp pass into the radicular pulp in bundles through the apical foramen. They divide into smaller bundles as they proceed coronally and peripherally to form nerve *Plexus of Rashkow* subjacent to the cell rich zone. Many of these fibers pass between the odontoblastic processes in the dentinal tubules.
  c) The pulp contains two types of sensory nerve fibers; myelinated (A fibers) and unmyelinated (C fibers).
  d) Approximately 90% of the A fibers in the dental pulp are A-delta fibers.
  e) Regardless of the nature of the sensory stimulus; thermal, mechanical, chemical, electric [e.g., pulp tester] almost all sensory impulses generated from pulp tissue result in the sensation of pain.

Clinical implication:

1. The A-delta fibers

- They are responsible for the initial, momentary, sharp pain to external stimuli because of their peripheral location, low threshold of excitability and great conduction speed.
- They are activated by the vitality tests (thermal and electric pulp tests) but since myelinated nerves do not reach their maximal development until the apices of teeth are complete; these tests are not reliable on immature teeth of young patients.

2. The C-fibers

- They are more resistant to compromises blood flow and hypoxic conditions and so pain associated by their stimulation is dull, poorly localized and throbbing.
- Pain associated with irreversibly damaged pulps is more likely to be caused by their stimulation.

Neuropeptides

- Are small protein-like molecules used by neurons to communicate with each other.
- Pulpal nerve fibers contain neuropeptides such as calcitonin gene–related peptide (CGRP), substance P (SP), neuropeptide Y, and neurokinin A (NKA).
- They play important role in regulating pulpal blood flow and the development of neurogenic inflammation.

Table (1) illustration of main types of sensory nerves of pulp.

	A delta fibers	C fibers
Myelination	Myelinated	Non-myelinated
Location of terminals	Superficial at pulp-dentin junction	Deep, distributed throughout pulp
Pain character	Sharp, fast, momentary, pricking, bearable	Throbbing, burning, dull, lingering, less bearable
Stimulation threshold	Low, stimulated without tissue damage	High, stimulated with tissue damage
Conduction velocity(m/sec)	Fast (6-30)	Slow (0.5-2)

- Release of these peptides can be triggered by numerous stimuli, including tissue injury, complement activation, antigen-antibody reactions, stimulation of inferior alveolar nerve, and even mechanical stimulation of dentin.
- Increased production and release of neuro peptides play an important role in initiating and propagating pulp inflammation.
- Once released, neuropeptides produce vascular changes that are similar to those evoked by histamine and bradykinin (causing vasodilatation of blood vessels)
- Vasoconstrictors present in local anesthetic solutions may have direct effects on inhibiting the release of neuropeptides and dental nerve activity thus reduce pain.

Age changes in the pulp

1. Continued formation of secondary dentin® decrease in the size of pulp chamber and canals.
2. Decrease cellularity.
3. Decrease number of nerves and blood vessels.
4. Increase number and thickness of collagen fibers.
5. Increase peritubular dentin, dentinal sclerosis and dead tracts® decrease in dentinal permeability.

CHAPTER REVIEW QUESTIONS

1. Describe morphologic zones of the pulp.
2. Discuss importance of neuropeptides in dental pulp nerves.
3. Give short account on factors affecting regulation of pulpal blood flow.
4. Discuss importance of the presence of undifferentiated mesenchymal stem cells in the dental pulp.

REFERENCES

- Fristad I. and Berggreen E. Cohen's Pathways of the Pulp. 11th ed. Mosby El Sevier, 2016.
- Kim S., Heyeraas K., and Haug S. Ingle's Endodontics 5.6th ed. BC Decker Inc., 2008.
- Mjör IA, Sveen OB, Heyeraas KJ. Pulp-dentin biology in restorative dentistry. Part 1: normal structure and physiology. Quintessence Int. 2001 Jun;32(6):427-46.
- Abd-Elmeguid A1, Yu DC.Dental pulp neurophysiology: part 1. Clinical and diagnostic implications. J Can Dent Assoc. 2009 Feb;75(1):55-9.
- Goldberg M, Kulkarni AB, Young M, Boskey A. Dentin: Structure, Composition and Mineralization: The role of dentin ECM in dentin formation and mineralization. Frontiers in Bioscience (Elite Edition) 2011;3: 711-735.

4 Endodontic Radiography

Alaa A. El Baz

Intended Learning objectives

After reading this chapter, the student should be able to

1. Describe the basic radiographic technologies and techniques .
2. Discuss special applications of radiography to Endodontics, and how to differentiate between endodontic and non-endodontic lesions.
3. Organize the reasons and the procedure of varying the horizontal and vertical cone angulations to create image shift (SLOB rule).
4. Plan how to detect the presence and to locate undiscovered canals on angled working radiographs.
5. Describe specific details of film placement and cone alignment for each tooth on working radiographs.
6. Evaluate digital imaging in endodontics and describe the difference between direct and indirect digital imaging
7. Discuss the advanced radiographic techniques for endodontic diagnosis
8. Point out the uses of cone beam computed tomography in endodontics.
9. Recognize the applications of advanced radiographic techniques
10. Correlate the importance of advanced radiographic techniques in diagnosis and treatment planning during endodontic therapy

Chapter Outline

Radiographs are the eyes of the dentist when performing many procedures. They are essential for diagnosis and treatment planning, determing anatomy, managing treatments and assessing outcome.

The discovery of the amazing properties of the cathode rays was made by Professor Wilhelm Konrad Roentgen in 1895. Four years later Dr Edmund Kells was the first to use x-ray to determine tooth length during root canal therapy.

Application of radiography to endodontics

1. Aids in diagnosis of hard tissue alterations of the teeth and periapical structures.
2. Determines the number, location, shape, size, and direction of roots and root canals.
3. Estimates and confirms the length of canals.
4. Localizes hard to find, or disclose unsuspected pulp canals by examining the position of an instrument within the root.
5. Aids in locating a pulp space markedly calcified and/or receded.
6. Determines the relative position of structures in the facial-lingual dimension.
7. Confirms the position and adaptation of master cones.
8. Aids in evaluation of obturation.
9. Facilitates the examination of soft tissues of tooth fragments and other foreign bodies following trauma.
10. Aids in localizing hard to find apex during root-end surgery.
11. Confirms, following root-end surgery and before suturing, that all tooth fragments and excess filling material have been removed from the apical region and the surgical flap.
12. Evaluates, on follow-up films, the outcome of treatment.

Limitations of radiographs

1. Radiographs are two-dimensional shadows on a single film. The buccal-lingual dimension is absent and frequently overlooked.
2. With any shadow the dimensions are easily distorted through improper technique, anatomic limitations, or processing errors.
3. Radiographs are not infallible. Various states of the pulpal pathosis are indistinguishable in the x-ray shadow. Bacterial status of hard or soft tissue is not detectable other than by interference.
4. Periradicular soft tissue lesions cannot be diagnosed by radiographs, they require histologic verification.

Technology systems

There are basically two radiographic approaches

1. The traditional approach is the x-ray exposure of a film that is chemically processed to produce an image.
2. The digital approach relies on an electronic detection of an x-ray generated image that is then electronically processed and reproduced on a computer screen.

Traditional machines

There are two basic types of x-ray machines

1. One type has a range of kilo-voltage and two milliamperage settings with which the long (16-inch) cone is frequently used.
2. The other type has one kilo-voltage and milliamperage setting using only the short (8-inch) cone.

Long cone

Because of the clarity of detail and minimum distortion inherent in the long cone parallel technique, the long-cone machine is preferred for exposing diagnostic, final, and follow-up radiographs. Fig. (1)

Short cone

Because of the number of working radiographs taken in the course of endodontic therapy, the practitioner treating more than the occasional tooth will find that a short-cone machine, with a small, easily manipulated heads, saves time, energy and frustration. Fig. (2)

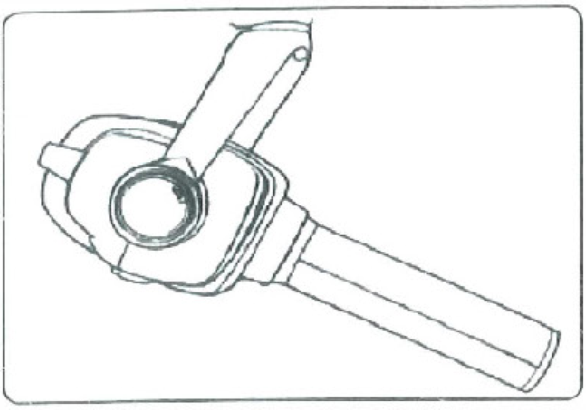


Fig. 1. Long cone on an x-ray machine

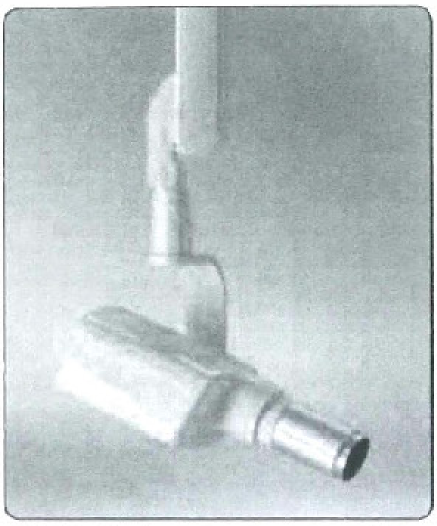


Fig. 2 Short cone on an x-ray machine

Film

Intraoral dental film is made up of a semiflexible, clear cellulose acetate film base that is coated on both sides with an emulsion of silver bromide, silver halide, and silver iodide that are sensitive to radiation. When the radiation interacts with the silver halide crystals in the film emulsion, the image on the film is produced. The film speed determines how much exposure time is required to produce the image on the film. A fast film requires less radiation, and the film responds more quickly because the silver halide crystals in the emulsion are larger. The ***larger*** the crystals, the ***faster*** the film speed. Industrial technological advances have allowed film exposure time to be reduced to fractions of a second. Recent improvements in emulsion thickness allow rapid processing of the new films, which are used for diagnostic and working films alike. Fig. (3).

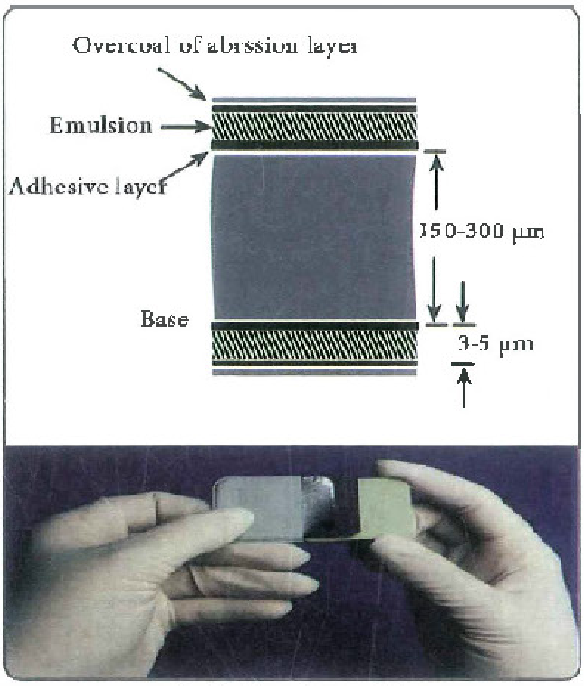


Fig 3. Dental x-ray film

For endodontists duplicate film packets are recommended for the diagnostic, final treatment, and recall radiographs (one set for the permanent office record, the other for the referring dentist). The front film in the double pack, the one closest to the x-ray machine has significantly superior image quality compared to the back films.

The standard periradicular size film is used for most situations. Every office should have **occlusal films** available for use when Fig. (4):

1. Periradicular lesions are so extensive that they cannot be demonstrated entirely on one periradicular film.
2. There is interest in involvement of the nasal cavity, sinuses, or roof or floor of the mouth.
3. Trauma or inflammation prohibits normal jaw opening required to place and hold a periradicular film.

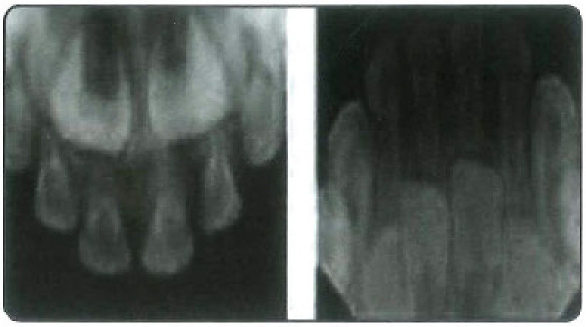


Fig. 4. Occlusal x-ray of upper and lower anterior teeth

4. A disabled person unable to hold a periradicular film by the usual means.
5. Detection of fractures of the anterior portion of the maxilla or mandible is needed.
6. Very young children are being examined.

Intraoral film placement

Paralleling technique

Film placed pararellel to the long axis of the teeth and exposed by cathode rays at a right angle to the surface of the film yields accurate images, with no shortening or elongation. Fig. (5,6)

Bisecting angle technique

A technique used when taking a periapical survey where the ray should be directed through the apical third of the targeted teeth. The maxillary apices can be determined by imagining a line from the tragus of the ear to the ala of the nose, which is roughly the level where the apices are located. The manibular apices are located about half an inch above the bottom of the mandible. The film center should be centered on the teeth being radiographed, except for a maxillary canine film, which is arranged slightly farther from the front and center of the jaw; the film should be kept flat as much as possible. The patient should be positioned so that their sagittal plane is at a right angle to the floor, and the occlusal plane is parallel to the floor. Fig. (7,8)

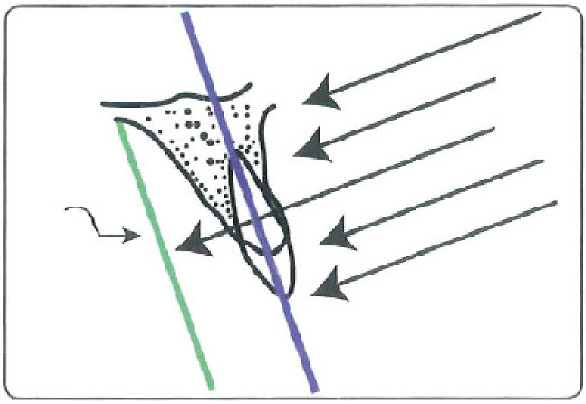


Fig. 5. Diagrammatic representation of the paralleling technique

Fig. 6. a

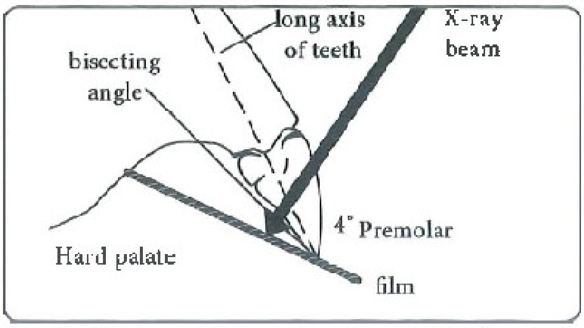


Fig. 7. Diagrammatic representation of bisecting angle technique

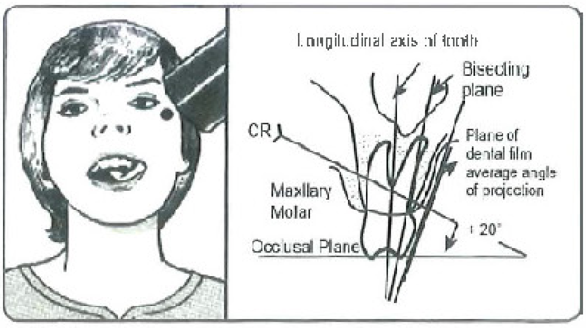


Fig. 8. Bisecting angle technique for maxillary molars

Diagnostic radiographs

These must be the best radiographs possible. There are advantages to parallelism that permits more accurate visualization of structures as well as reproducibility. This facilitates comparison of follow-up radiographs. A number of devices are available on the market that ensures film placement and parallelism as the Rinn XCP, the RinnEndoray II endodontic film holder Fig. (9,10). A disadvantage of this system is that the paralleling bar interferes with the cone when varying the horizontal cone angulations. Finger retention of the film should never be used. A straight hemostat is a good film holder and additionally servers as a cone-positioning device. Fig. (11)

Working radiographs

One great difficulty in root canal therapy is the aggravating method of making treatment radiographs with the rubber dam in place. The rubber dam frame should not be removed for access in film placement because doing so allows saliva entry to contaminate the operating field. A film-placement technique is used so that the rubber dam need not be removed. Use of radiolucent N-Ø (Nygaard- Østby) frame, Lexicon hinge dam frame, or the Star VisiFrame will ensure that apices are not obscured.

With the rubber dam in place, a hemostat-held film has significant advantages:

1. The film placement is easier when the opening is restricted by the rubber dam and frame.
2. The patient may close somewhat with the film in place, a particular advantage in mandibular posterior areas where closing relaxes the mylohyoid muscle, permitting the film to be positioned farther apically.
3. The handle of the hemostat is a guide to align the cone in the proper vertical and horizontal angulations.
4. There is less risk of distortion of the radiograph caused by too much finger pressure bending the film.

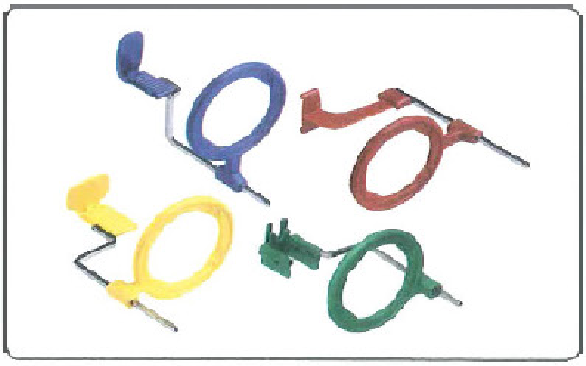


Fig. 9 XCP film holders

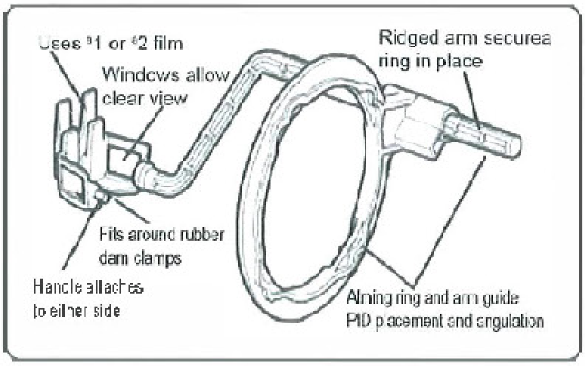


Fig. 10. EndoRay II employing the paralleling technique

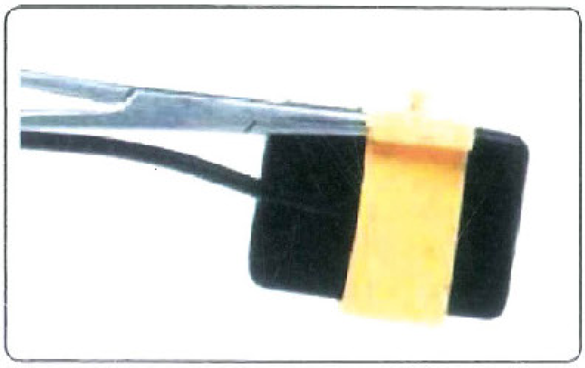


Fig. 11 Hemostat acting as a film holder

5. Patients can hold a hemostat handle more securely with less possibility of film displacement
6. Any movement can be detected by the shift of the handles and corrected before exposure.

The **identify dimple** should be placed at the incisal or occlusal edge to prevent its obscuring an important apical structure.

Cone positioning

It is often a mistake to rely on only one film. Additional exposures taken from varied horizontal or vertical projections give visualization of the third dimension.

1. Vertical angulation

   It is preferable to align the cone so that the beam strikes the film at a right angle. This alignment ensures a fairly accurate vertical image. Elongation of an image, however, may be corrected by increasing the vertical angle of the central ray. Foreshortening is corrected by decreasing the vertical angle of the central ray. Frequently an impinging palatal vault prevents parallel alignment of the film and the teeth. However, if the film angle is no greater than 20° in relation to the long axis of the teeth, and the beam is directed at a right angle to the film, no distortion occurs. The resulting radiograph is still adequate. Fig. (12)

2. Horizontal angulation: Walton demonstrated a simple technique whereby the third dimension may be readily visualized. Specifically, the anatomy of superimposed structures, the roots and the pulp canals, may be better defined. The basic technique is to vary the horizontal angulation of the central ray of the x-ray beam. By this method, overlying canals may be separated, and by applying Clark's rule, the separate canals may then be identified. Clark's rule states that "the most distant object from the cone (lingual) moves toward the direction of the cone". Stated in another way, Clark's rule has been referred to as the SLOB rule (same lingual, opposite buccal): the object that moves in the same direction as the cone is located toward the lingual. The object that moves in the opposite direction from the cone is located toward the buccal. The SLOB rule, simply stated, is 'the lingual object follows the tube head'. Stated more simply, Ingle's rule is MBD: always shoot from the mesial and the buccal root will be to the distal Fig. (13,14,15)

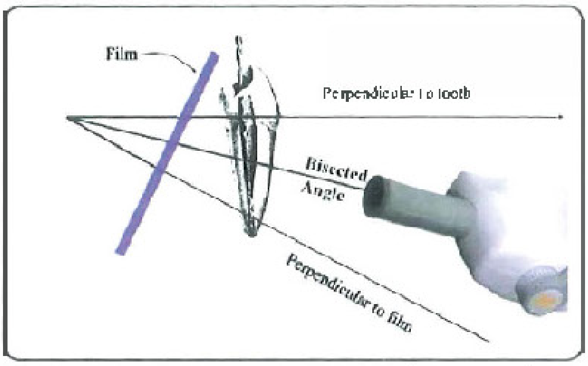


Fig. 12. Position the x-ray tube so that it is perpendicular to the film and note the angle of the tube. Call this position 1. Then reposition the tube so that it is perpendicular to the tooth itself. Call this position 2. Finally, reposition the tube so that it is at an angle that is exactly between position 1 and position 2. This is the angle which will produce the least distorted shadow of the tooth in question

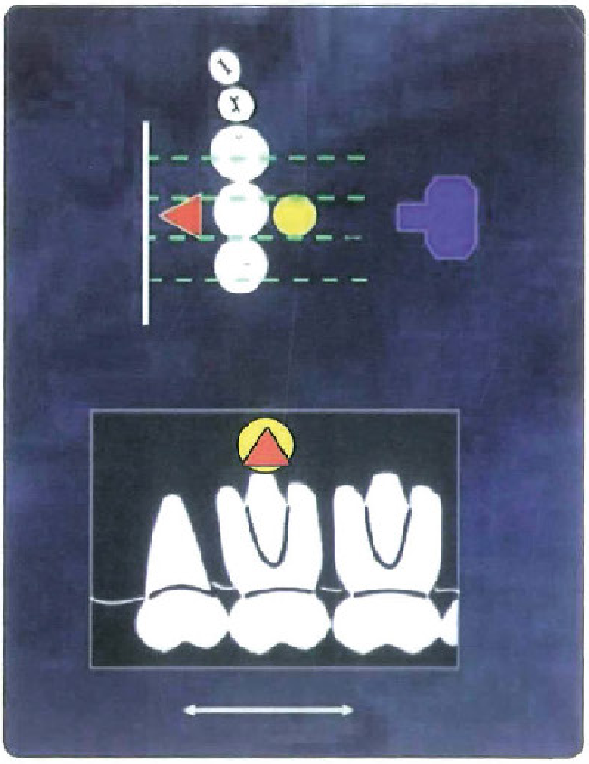


Fig. 13. In the diagram, the buccal (yellow) and the lingual (red) objects of interest are superimposed on each other because of the beam is directed perpendicular to both of them and they are in the same relative position mesio-distally and vertically. Both images are located above the second molar.

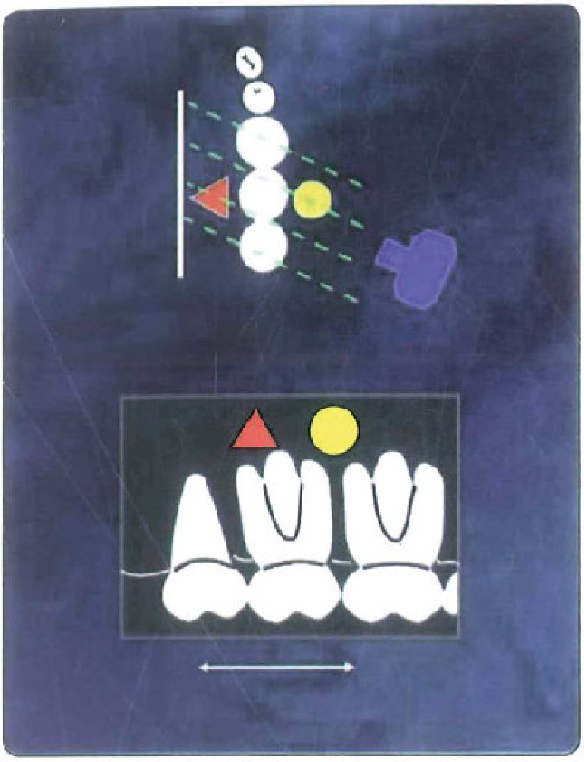


Fig. 14 The tube-head is moved distally and the beam is directed mesially. On the radiograph the buccal object (yellow)moves mesially (opposite to the tube head)in relation to the second molar and the lingual object (red) moves distally (same direction of the tube head) in relation to the second molar.

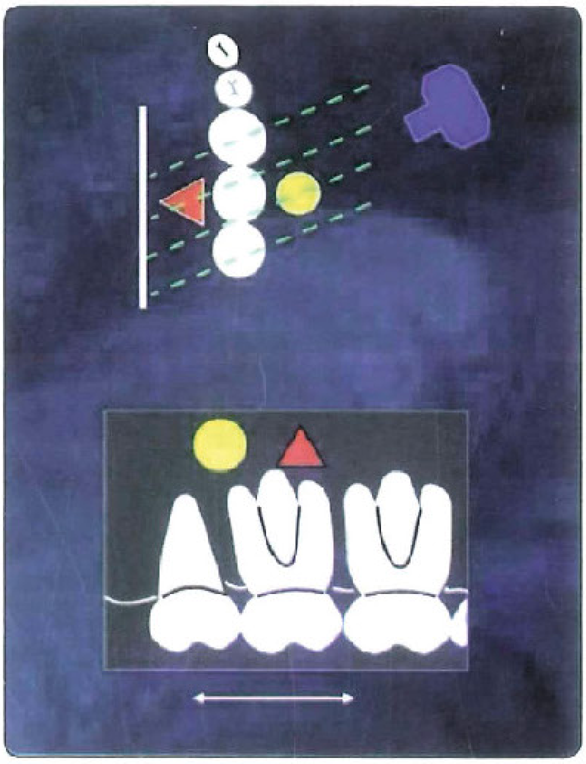


Fig. 15 The tube-head is moved mesially and the beam is directed distally. On the radiograph the buccal object (yellow) moves distally (opposite to the tube head)in relation to the second molar and the lingual object (red) moves mesially (same direction of the tube head) in relation to the second molar.

Indications and advantages of the SLOB rule are:

I. Separation and identification of superimposed canals.
II. Movement and identification of superimposed structures.
III. Determination of working length.
IV. Determination of curvatures.
V. Determination of faciolingual locations.
VI. Identification of undiscovered canals.
VII. Location of calcified canals.

Disadvantages of the SLOB rule are:

I. Decreased clarity.
II. Superimposition of structures.

To summarize, angled cone alignment are as follows:

- Facial for maxillary anterior teeth and maxillary molars with only one mesiobuccal canal
- Mesial for maxillary and mandibular premolars and mandibular canines, also for maxillary molars with more than one mesiobuccal canal.
- Distal for mandibular incisors and mandibular molars.

Extraoral film placement

This is useful for patients who cannot accommodate or tolerate intraoral film placement, usually because of gagging or trismus.

Processing

Adherence to the manufacturer's recommended temperature and time (68°F for 5 to 7 minutes) developing and clearing has hampered "on the spot" processing and viewing. For rapid processing, small quart-size tanks are adequate and economical. Frequent change of solutions is recommended.

Rapid processing solutions

Concentrated chemicals, such as Kodak's Rapid Access solution, have become very popular in endodontic practice. Although more expensive, they save measurable time, requiring only 15 seconds developing and 15 seconds clearing time in the fixer at room temperature. These rapidly processed films will fade or discolor with time. This change can be prevented, after viewing, by returning the wet film for a few minutes of fixation, followed by washing for 30 minutes, and then drying. The films will retain their quality indefinitely.

Table-top developing

For quick turnaround and ease of processing, combining rapid speed solutions with a table top processing hood greatly improves radiographic reporting.

Viewers

There are several types of radiographic viewers, both commercial and adapted. Commercial viewers magnify the image and block out peripheral light. This enhances the readability and interpretation of the film. Other techniques or adaptations, such as a standard magnifying glass and small slide viewers, are also useful.

Endodontic radiographic anatomy

Interpretation

Radiographs can be termed the great pretenders, they often are as misleading as they are hepful. The practitioner must remember that only hard tissues, not soft tissues, are visible.

Limitations

Studies of interpretation of bony lesions have shown that considerable bone must be resorbed before the lesion is clearly visible. This, of course, varies with root location and thickness of the overlying cortical bone. In most regions, a periradicular lesion tends to be most evident radiographically if cortical bone has resorbed.

Differential diagnosis

Endodontic pathosis

Radiolucent lesions

Radiolucent lesions have the following four distinguishing characteristics that aid in differentiating them from nonendodontic pathoses:

- Apical/radicular lamina dura is absent.
- A hanging drop of oil shape is characteristic of the radiolucency.
- The radiolucency stays at the apex regardless of cone angulations.
- A cause of pulp necrosis is usually (but not always) evident.

Radiopaque lesions

Radiopaque lesions are better known as condensing osteitis. The radiographic pattern is one of diffuse borders and a roughly concentric arrangement around the apex. Pulp necrosis and a radiolucent inflammatory lesion may or may not be present. Frequently condensing osteitis and apical periodontitis are present together. The pulp is often vital and inflamed.

Nonendodontic pathosis

Radiolucent lesions

Such lesions have a varity of configurations and locations, and many are positioned close to the apexes and radiographically mimic endodontic pathosis. Pulp testing provides the cardinal differentiation, nonendodntic lesions are associated with a responsive tooth.

Radiopaque lesions

Unlike condensing osteitis they are not pathologic and have a more well-defined border and a homogeneous structure. They are not associated with pulp pathosis.

Anatomic structures

Several anatomic entities are superimposed on or may be confused with endodontic pathosis. Common sources of confusion are the areas created by sparse trabecular patterns, particularly in the mandible. Another problem

area is the apical region of the maxillary anterior teeth. One must remember to look through these radiolucencies for an apical lamina dura.

Mandible

The classic example of a radiolucency that overlie an apex is the mental foramen over a mandibular premolar. This is easily identified by noting movement on angled radiographs and by identifying the lamina dura.

Maxilla

The maxilla region contains several structures (both radiolucent and radiopaque) that may be confused with endodontic pathosis. Examples are the maxillary sinus, incisive canal, nasal fosa, zygomatic process, and anterior nasal spine. Characteristics of the structure, as well as pulp responsiveness to tests, are important in differentiation.

Digital imaging for endodontics

Radiography is an important adjunct to endodontic diagnosis and image-guided treatment. The use of digital technologies can facilitate the process by speeding image acquisition and display. The invention of digital intraoral radiography started in the 1970s by Mouyen a dentist graduated from the University of Toulouse. He developed a prototype digital radiographic system that he named RadioVisioGraphy (RVG). Since 1989, there has been seven new generations of RVG, and there are now many alternate solid-state systems that can produce almost instant images electronically. Although these images are essentially instant, most are not direct as the solid-state systems, for the most part, employ a scintillator to convert x-ray to light, and it is the analogue light signal that is then converted to a digital image. Furthermore, it is possible to replace silver halide film by photostimulable phosphor (PSP) plates that interact directly with x-ray but require the added step of subsequent processing by laser scanning to convert the latent image to one that can be viewed on a computer monitor screen. Fig. (16).

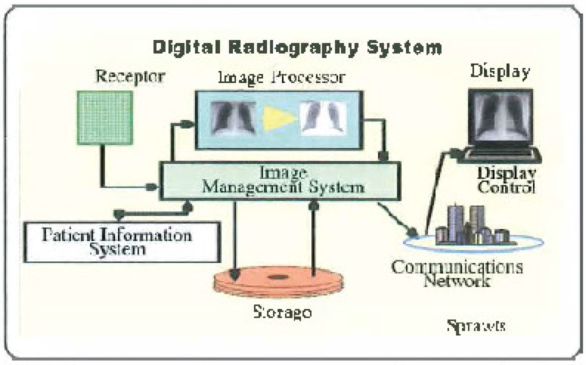


Fig. 16. Diagrammatic representation of digital radiographic system

Disadvantages of conventional x-ray film include the following:

1. Inefficiency as photon detectors, therefore requiring a relatively high radiation exposure.
2. Film packet is thin and can be felt by the patient to cut into the tissues.
3. Film is not rigid and hence can bend resulting in distorted radiographic image.
4. Produce static images with no availability of post-image treatments other than varying the brightness of the view-box illumination.
5. Exposure errors and suboptimal processing conditions can result in poor image quality that is not immediately obvious.
6. Film processing is relatively time-consuming.
7. Costs for maintaining a darkroom.
8. Silver in spent processing chemicals has the potential to cause environmental pollution.
9. Duplicate radiograph in a double film packet is of very slightly lower density compared with the top film. Physicochemical duplication of film radiographs results in copies of higher contrast and less detail.
10. Archiving radiographic film radiographs in physical patient files requires extra storage space in the office. Retrieving radiographs can take time.
11. Intraoral film radiographs not appropriately mounted and labeled cannot in themselves be associated for certainty with a given patient or time of exposure.

Digital radiography

Indirect digital radiography

To take a periapical exposure, place a small photosensitive imaging plate (coated with phosphorus) into a sterile wrapper and insert it into the patient's mouth just like a conventional X-ray film. The X-ray is taken, and the exposed plate is then loaded into a scanner, or processor, which reads the image and converts it to digital form. Imaging plates can be re-used thousands of times, and they are available in different sizes to match conventional x-ray films, including panoramic and pan/ceph.

Direct digital radiography

Direct digital radiographs bypass the scanning step and are loaded directly into the computer. Intraoral radiographs are taken on electronic sensors covered with a sterile wrapping. Sensors are about the same size as periapical film cards or imaging plates, although a bit thicker. However, the major difference is that a sensor is attached to a long, thin wire which plugs into a port in the computer. The captured image is loaded directly into the computer with no scanning required. Fig. (17).

The two major technologies presently used in intraoral digital x-ray systems are as follows:

1. **Solid state detectors**

a. Charged- coupled device

The first-generation intraoral solid-state sensors used CCD technology. Numerous drawbacks existed with these sensors. Currently available systems have worked around these drawbacks, which included, among others, a relatively smaller active area, bulkiness, and lower absorption and conversion efficiency of incident radiation. These solid-state sensors use an array of radiation-sensitive or light-sensitive elements that quantify the intensity of the incident radiation (X-ray or light) by generating a proportional electric charge that is then read as a voltage. These readings are then transferred to an analog-to-digital converter in

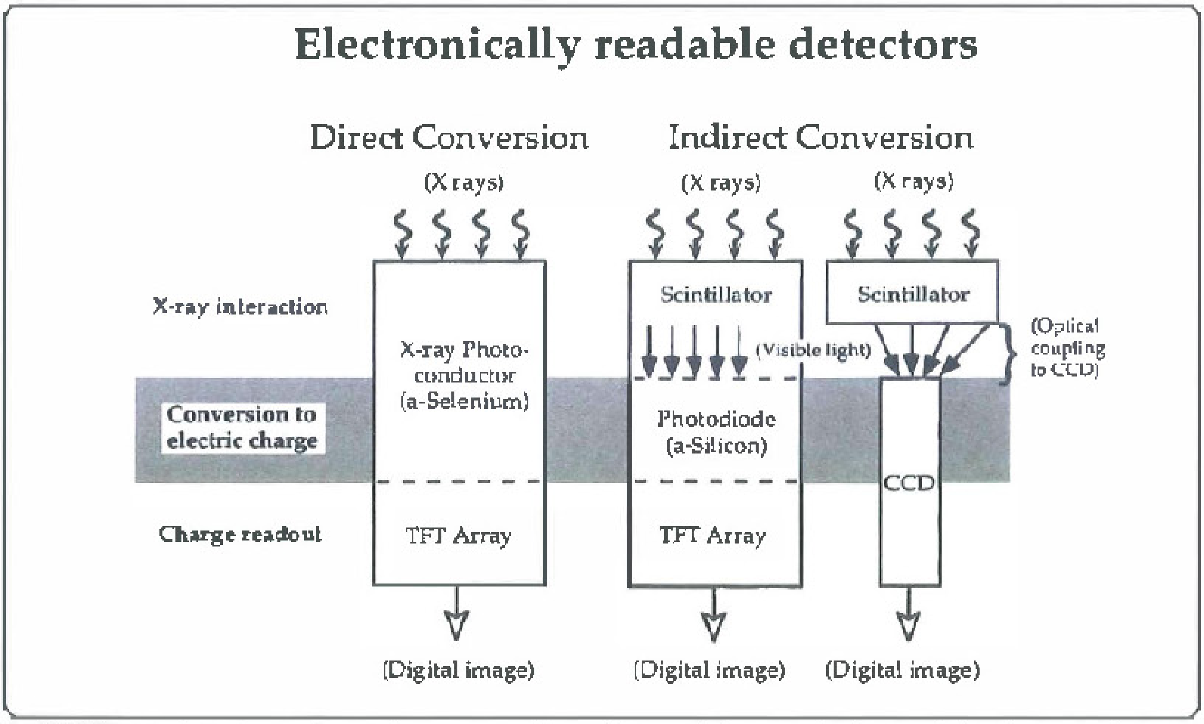


Fig. 17. Direct-readout electronic x-ray detectors use either a direct technique or an indirect techniquefor converting x rays into an electric charge

the frame-grabber assembly. Once digitized, these signals are converted into analog signals for viewing on the monitor. To enhance the efficiency of the sensor and reduce the radiation dose, a scintillation layer, such as a phosphor material, is added to the surface of the detector array to facilitate conversion of incident X-rays to light. This layer is painted onto the CCD chip or laid over the CCD with fiber-optic coupling. Sensor sizes vary and are now available in sizes comparable to those of # 0, 1, and 2 intraoral films, with active areas approaching similar dimensions. Instantaneous image generation is possible with solid-state sensors. Fig. (18)

b. Complimentary metal oxide semiconductor (CMOS)

CMOS-based sensors are also used for similar image acquisition. The sensor has an active transistor at each element location. It uses less power and is less expensive to manufacture. Wired and wireless sensors are also available. Comparison of the objective, task-based, image quality of the CMOS with earlier generation CCD-based detectors showed no difference in diagnostic capabilities. Fig. (19)

2. Storage phosphor detectors

a. Photostimulable phosphor

PSP sensors were introduced in the mid-1980s as Fuji computed radiography, although the physics of phosphorescence and latent image formation were known for a long time. Intraoral, panoramic, and cephalometric size sensors have since become available. PSP imaging is also referred to as computed radiography (CR), photostimulable phosphor radiography (PPR), and storage phosphor radiography. The devices are wireless, thin sensors that record a latent image upon exposure to radiation. The images can be erased by exposing the sensor to intense white light, making the sensor reusable. Associated problems unique to this technology include the potential for physical damage sustained by the plates being scratched and incomplete erasure of previous images, resulting in ghost images. Sensors are relatively inexpensive. The dynamic range is significantly higher than that of solid state sensors; resolution is slightly less. However, for most diagnostic tasks indentistry, PSP sensors have been shown to be as good as CCD/CMOS sensors. Fig. (20)

Fig 18. CCD sensor

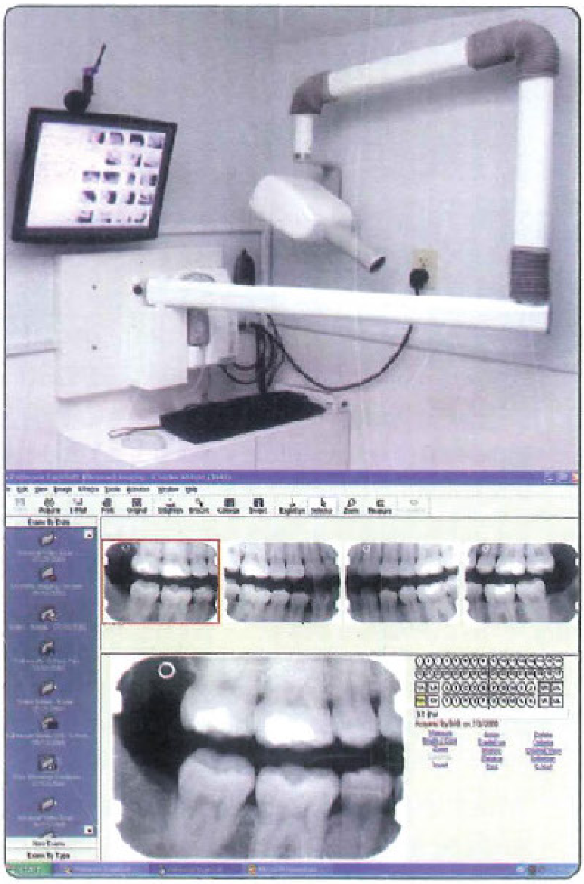


Fig 19. Digital x ray machine

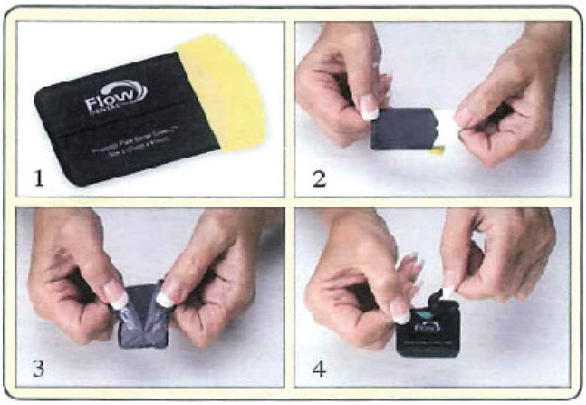


Fig. 20. PSP sensor

Advantages of digital x-ray imaging:

1. Reduced time between exposure and image formation when using solid-state detectors.
2. Reduced radiation dose per image.
3. Multiple exposures, from various angles, both vertical and horizontal, may be made without moving the sensor once positioned.
4. Elimination of chemical processing and disposal of spent chemicals.
5. Images can be duplicated any number of time without any loss of image quality.
6. Images can be stored and retrieved electronically.
7. Images can be transmitted electronically for referrals and other purposes.
8. Dynamic nature of the image with the ready option of post-imaging enhancements.
9. Digital systems also have measurement tools that given a suitably positioned fiducial reference.
10. Reusable detector reduces expenditure on consumables.
11. With DICOM image file usage, digital images can provide greater security regarding radiographic image integrity and tags include such information as patient name, date of exposure, and laterality.
12. Wired detectors have an advantage when working on special needs patients as the wire makes swallowing or ingesting the detector unlikely.

Disadvantages of digital imaging over films:

1. Relatively high initial investment cost if the practice has previously sunk costs in film-processing facilities.
2. Issues related to infection control as the detectors cannot be autoclaved.
3. Solid state detectors are somewhat thicker and more rigid.
4. Packaged PSP imaging plates (IPs) are thinner than prepackaged analog intraoral x-ray films and may not be held firmly in position in film holders.
5. CCD and CMOS detectors are wired; this could create patient psychological discomfort. It might also be a drawback for the inexperienced operator, requiring adjustments in technique and practice through the learning curve of a new methodology.
6. Competency using software may take time to master. The learning curve may be longer or shorter depending on the computer literacy of the operator.
7. With PSPs the intraoral imaging plates have been prone to mechanical degradation necessitating replacements of plates to sustain image quality.
8. Although unlikely to occur given reasonable diligence, mishandling can cause mechanical damage with high replacement costs for CCD and CMOS detectors.

Digital subtraction radiography

Given radiographs taken in precisely the same position and with the same beam geometry and exposure parameters, images can be subtracted to show changes over time. This technique has been largely conducted for research purposes in view of the difficulties experienced in practice in achieving images with reproducible projection geometry over time. Subtraction radiology is possible for endodontic follow up, effect of root canal treatment on periapical lesions and for assessment of the progress of chronic apical periodontitis. Fig. (21)

Advanced radiographic techniques for endodontic diagnosis

Alternative imaging techniques have been suggested to overcome the limitations of intra-oral radiographs. In endodontics, some of these techniques may improve the diagnostic yield and assist clinical management.

Tuned aperture computed tomography (TACT)

Tuned aperture computed tomography works on the basis of tomosynthesis. A series of 8–10 radiographic images are exposed at different projection geometries using a programmable imaging unit, with specialized software to reconstruct a three-dimensional data set which may be viewed slice by slice. Claimed advantages of TACT over conventional radiographic techniques are that the images produced have less superimposition of anatomical noise over the area of interest. The overall radiation dose of TACT is no greater than 1–2 times that of a conventional periapical X-ray film as the total exposure dose is divided amongst the series of exposures taken with TACT. Additional advantages claimed for this technique include the absence of artifacts resulting from radiation interaction with metallic restorations. The resolution is reported to be comparable with two dimensional radiographs. Studies concluded that the complex nature of the adjacent anatomy around posterior maxillary molar teeth limits the use of TACT. Recently, studies have concluded that TACT is suitable for detecting vertical root fractures. Tuned aperture computed tomography appears to be a promising radiographic technique for the future. However, at present it is still only a research tool. Fig. (22)

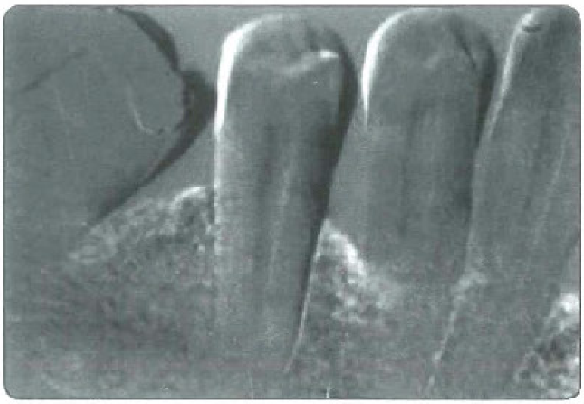


Fig. 21. Subtraction radiography showing a bone density gain on the mesial aspect of the mandibular first molar and mandibular first premolar

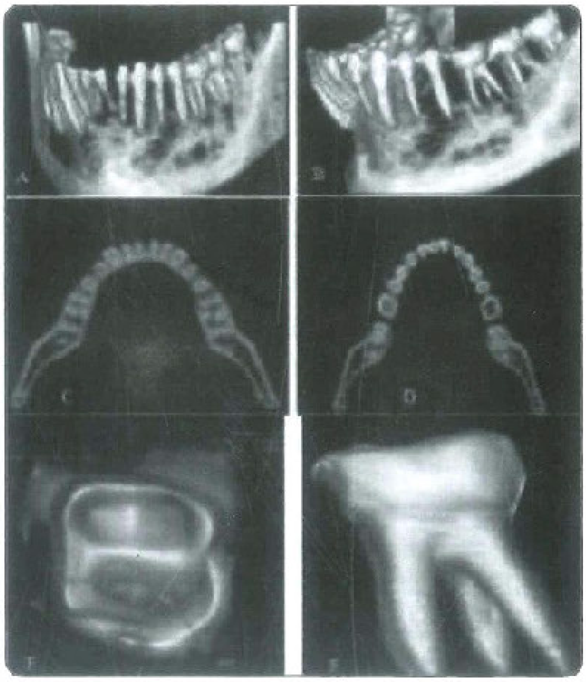


Fig. 22. TACT image showing the extra distolingual root canal in the lower molar

Magnetic Resonance Imaging (MRI)

An MRI scan is a specialized imaging technique which does not use ionizing radiation. It involves the behaviour of hydrogen atoms (consisting of one proton and one electron) within a magnetic field which is used to create the MR image. The patient's hydrogen protons normally spin on their axis. The patient is placed within a strong magnetic field, which aligns the protons contained within hydrogen atoms along the long axis of the magnetic field and the patient's body. A pulsed beam of radio waves which has a similar frequency to the patient's spinning hydrogen atoms is then transmitted perpendicular to the magnetic field. This knocks the protons out of alignment, resulting in the hydrogen protons precessing like tiny gyroscopes, moving from a longitudinal to a transverse plane. The atoms

behave like several mini bar-magnets, spinning synchronously with each other. This generates a faint radio-signal (resonance) which is detected by the receiver within the scanner. Similar radio-signals are detected as the hydrogen protons relax and return to their original(longitudinal) direction. The receiver information is processed by a computer, and an image is produced. The main dental applications of MRI to date have been the investigation of soft-tissue lesions in salivary glands, investigation of the temporomandibular joint and tumour staging. MRI has also been used for treatment planning dental implant placement. Recently, studies were performed with MRI on a series of patients with dental disease. They were able to differentiate the roots of multi-rooted teeth; smaller branches of the neurovascular bundle could be clearly identified entering apical foramina. The authors also claimed that the nature of periapical lesions could be determined as well as the presence, absence and/or thickening of the cortical bone. Magnetic resonance imaging has several drawbacks. These include: poor resolution compared with simple radiographs and long scanning times, in addition to great hardware costs and limited access only in dedicated radiology units. Different types of hard tissue (for example enamel and dentine) cannot be differentiated from one another or from metallic objects; they all appear radiolucent. It is for these reasons that MRI is of limited use for the management of endodontic disease. Fig. (23)

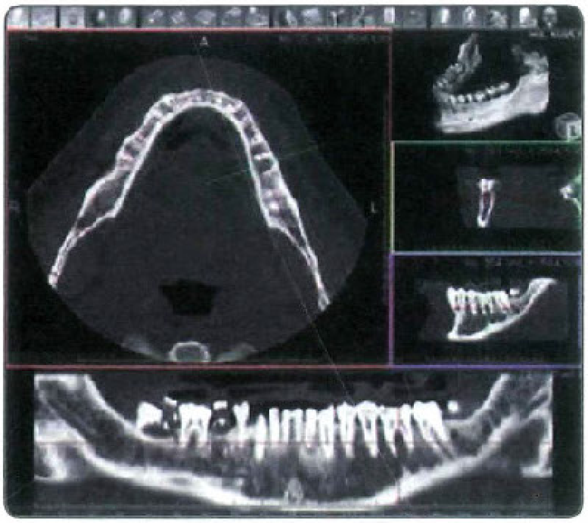


Fig. 23. MRI image of the mandible

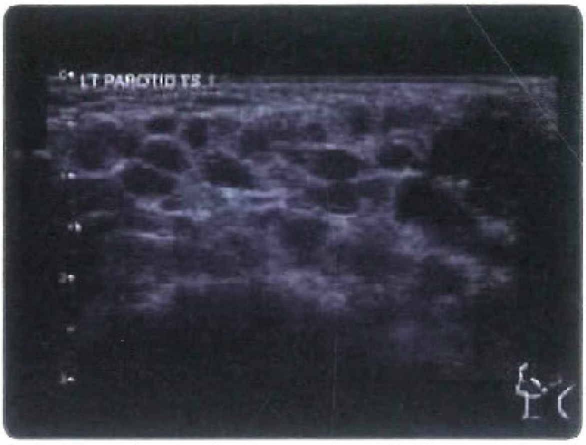


Fig. 24. Ultrasound of parotid gland

Ultrasound (US)

Ultrasound is based on the reflection (echoes) of US waves at the interface between tissues which have different acoustic properties. Ultrasonic waves are created by the piezoelectric effect within a transducer (probe). The US beam of energy is emitted and reflected back to the same probe (i.e. the probe acts as both the emitter and detector). The echoes are detected by a transducer which converts them into an electrical signal, from which a real time black, white and shades of grey echo picture is produced on a computer screen. As the probe is moved over the area of interest, a new image is generated. Up to 50 images can be created per second, resulting in moving images on the screen. The intensity or strength of the detected echoes is dependent on the difference between the acoustic properties of two adjacent tissues. The greater the difference between tissues, the greater the difference in the reflected US energy and the higher the echo intensity. Tissue interfaces which generate a high echo intensity are described as hyperechoic (e.g. bone and teeth), whereas anechoic (e.g. cysts) describes areas of tissues which do not reflect US energy. Typically, the images seen consist

of varying degrees of hyperechoic and anechoic areas as the areas of interest usually have a heterogeneous profile. The Doppler Effect (the change of frequency of sound reflected from a moving source) can be used to detect the arterial and venous blood flow. The ability of US to assess the true nature and type (for example true versus pocket cyst) of periapical lesions is doubtful. Ultrasound is blocked by bone and is therefore useful only for assessing the extent of periapical lesions where there is little or no overlying cortical bone. Whilst US may be used with relative ease in the anterior region of the mouth, the positioning of the probe is more difficultagainst the buccal mucosa of posterior teeth. In addition, the interpretation of US images is usually limited to radiologists who have had extensive training in the use and interpretation of US images. Fig. (24)

Computed Tomography (CT)

Computed Tomography is an imaging technique which produces three dimensional images of an object by taking a series of two-dimensional sectional X-ray images. Essentially, CT scanners consist of a gantry which contains the rotating X-ray tubehead and reciprocal detectors. In the center of the gantry, there is a circular aperture, through which the patient is advanced. The tubehead and reciprocal detectors within the gantry either rotate synchronously around the patient, or the detectors take the form of a continuous ring around the patient and only the X-ray source moves within the gantry The data from the detectors produce an attenuation profile of the particular slice of the body being examined. The patient is then moved slightly further into the gantry for the next slice data to be acquired. The process is repeated until the area of interest has been scanned fully. Early generations of the CT scanner acquired 'data' in the axial plane by scanning the patient 'slice by slice' using a narrow collimated fan shaped X-ray beam passing through the patient to a single array of reciprocal detectors. The detectors measured the intensity of X-rays emerging from the patient. Over the last three decades, there have been considerable advances in CT technology. Current CT scanners are called multislice CT (MSCT) scanners and have a linear array of multiple detectors, allowing 'multiple slices' to be taken simultaneously, as the X-ray source and detectors within the gantry rotate around the patient who is simultaneously advanced through the gantry. This results in faster scan times and therefore a reduced radiation exposure to the patient. The slices of data are then 'stacked' and reformatted to obtain three-dimensional images and multiplanar images which can be viewed in any plane the operator chooses (for example axial, coronal or sagittal) without having to expose the patient to further radiation. The interval between each slice may also be varied; closely approximated slices will give better spatial resolution, but will result in an increased radiation dose to the patient.

In addition to three-dimensional images, CT has several other advantages over conventional radiography. These include the elimination of anatomical noise and high contrast resolution, allowing differentiation of tissues with less than 1% physical density difference to be distinguished compared with a 10% difference in physical difference which is required with conventional radiography. Computed tomography technology has been applied to the management of endodontic problems. However, one should bear in mind that a very high radiation dose is required to achieve a high enough resolution to assess root canal anatomy in adequate detail with CT. Computed tomography may also be useful for the diagnosis of poorly localized odontogenic pain. In these circumstances, conventional radiographs of the periapical tissues may not reveal anything untoward. In these cases, CT may confirm the presence of a periapical lesion. The assessment of the 'third dimension' with CT imaging also allows the number of roots and root canals to be determined, as well as where root canals join or divide. This knowledge is extremely useful when diagnosing and managing failing endodontic treatment. The uptake of CT in endodontics has

been slow for several reasons, including the high effective dose and relatively low resolution of this imaging technique. Other disadvantages of CT are the high costs of the scans, scatter because of metallic objects, poor resolution compared with conventional radiographs and the fact that these machines are only found in dedicated radiography units (for example hospitals). Access may thus be problematic for dentists in practice. CT technology has now become superceded by cone beam computed tomography (CBCT) technology in the management of endodontic problems. Fig. (25)

Cone beam computed tomography (CBCT)

Cone beam computed tomography or digital volume tomography is an extra-oral imaging system which was developed in the late 1990s to produce three-dimensional scans of the maxillo-facial skeleton at a considerably lower radiation dose than CT. CBCT differs from CT imaging in that the entire three-dimensional volume of data is acquired in the course of a single sweep of the scanner, using a simple, direct relationship between sensor and source which rotate synchronously around the patient's head. Depending on the CBCT scanner used, the X-ray source and the detector rotate between 180° and 360° around the patient's head. Unlike CT scanners, most CBCT scanners either scan the patient sitting or standing up. The X-ray beam is cone-shaped (hence the name of the technique), and captures a cylindrical or spherical volume of data, described as the field of view Fig. (26). Voxel size typically ranges between 0.08 and 0.4 mm. Its major advantage over CT scanners is the substantial reduction in radiation exposure. This is because of rapid scan times, pulsed X-ray beams and sophisticated image receptor sensors. The pulsed X-ray beam results in up to 570 projections or basis exposures being taken as the X-ray source and detector rotate around the patient. CBCT scanners are simple to use and take up about the same space as Panoramic radiographic machines, which make CBCT scanners well suited for dental practice. The radiation dose may be further reduced by decreasing the size of the field of view, increasing

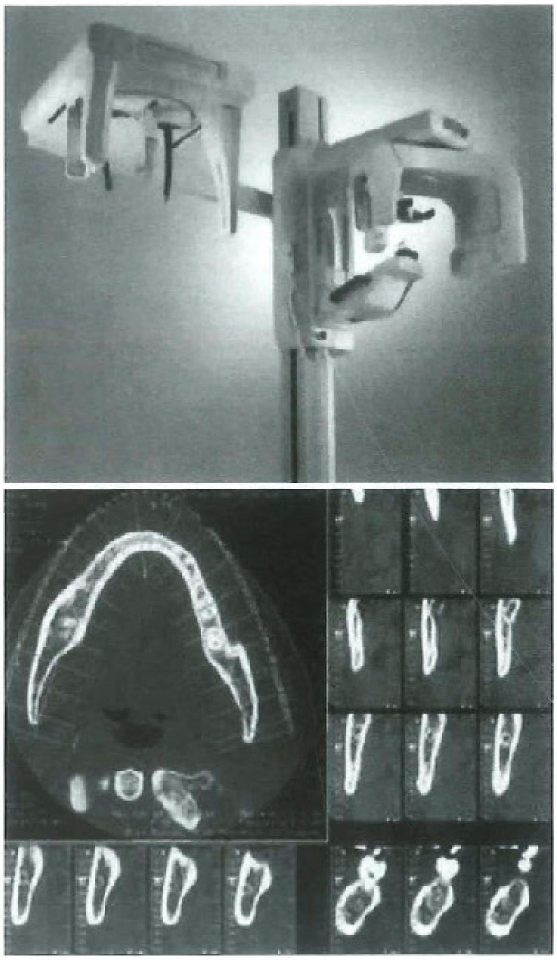


Fig. 25. Dental CT machine and a dental CT scan image

the voxel size and/or reducing the number of projection images taken as the X-ray source rotates around the patient. Tomographic slices, as thin as one voxel thick, maybe displayed in a number of different ways. Typically, images are displayed in the three orthogonal planes axial, sagittal and coronal simultaneously. Selecting and moving the cursor on one image simultaneously alters the selected reconstructed slices in all three planes, thus allowing the area of interest to be dynamically traversed in 'real time'. Coronal and axial views of the tooth are readily produced, allowing the clinician to gain a truly three-dimensional view of the entire tooth and its surrounding anatomy. Surface rendering is also possible to produce three-dimensional images. The image quality of CBCT scans is superior to helical CT for assessing the dental

hard tissues. Cone beam computed tomography is a major break through in dental imaging. For the first time, the clinician is able to use a patient-friendly imaging system to easily view areas of interest in any plane rather than being restricted to the limited views available up to now with conventional radiography. CBCT technology is increasingly being used successfully in the management of endodontic problems. Fig. (27)

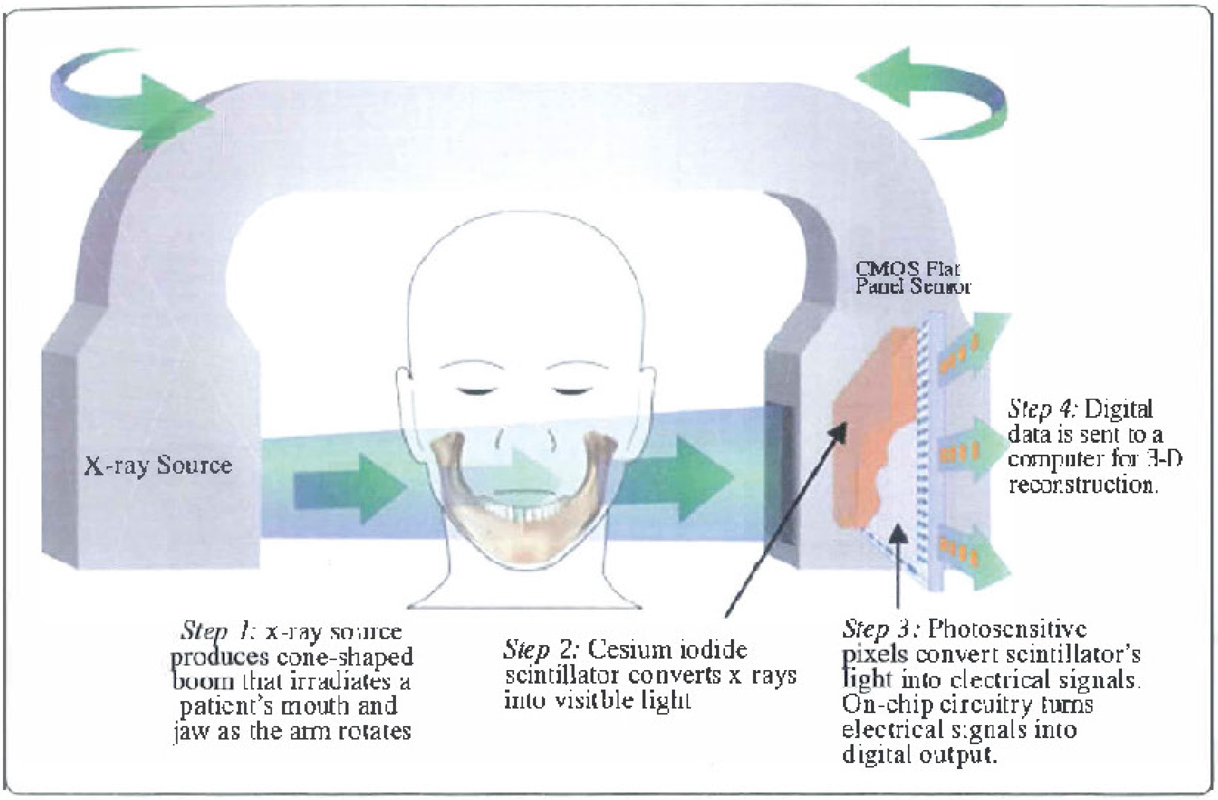


Fig. 26. In cone beam computed tomography, a cone-shaped x-ray beam irradiates a patient's jaw. The transmitted x-rays are detected by a sensor such as a CMOS flat panel sensor. The data is sent to a computer and reconstructed into 3 D images by software

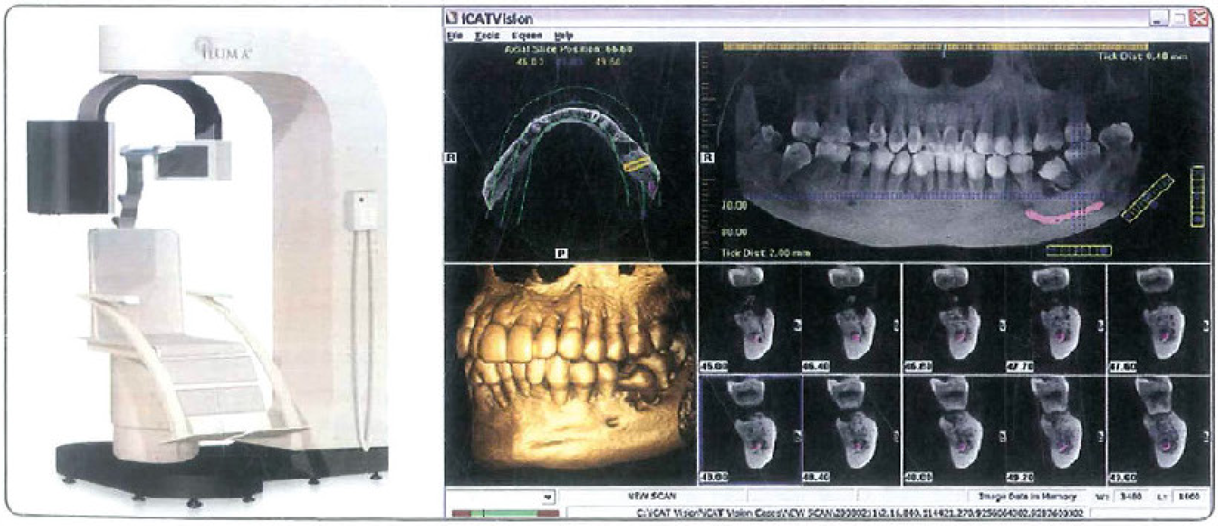


Fig. 27. A CBCT machine and a dental CBCT scan image

Applications of CBCT in endodontics:

1. Preoperative assessment

- *Tooth morphology:* The success of endodontic treatment depends on the identification of all root canals so that they can be accessed, cleaned, shaped, and obturated Fig. (28,29).

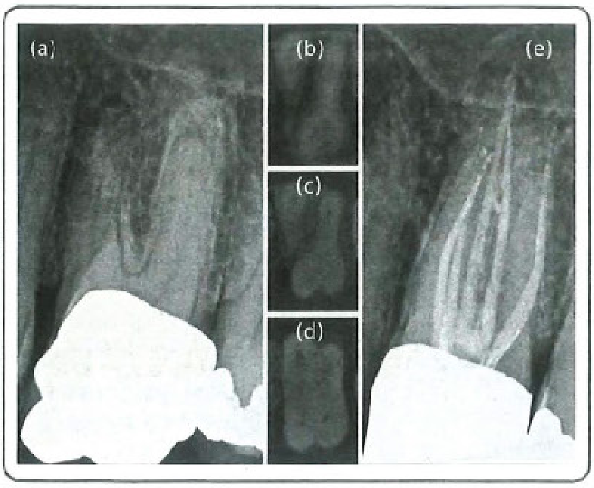


Fig. 28 Preoperative periapical radiograph of a maxillary left first molar (a) with corresponding axial CBCT slices captured from the apical third (b), mid-root (c), and coronal third (d) demonstrating five separate root canal systems (two canals in the mesiobuccal root and two canals in the palatal root). The post-endodontic periapical radiograph demonstrates all identified root canal systems treated (e)

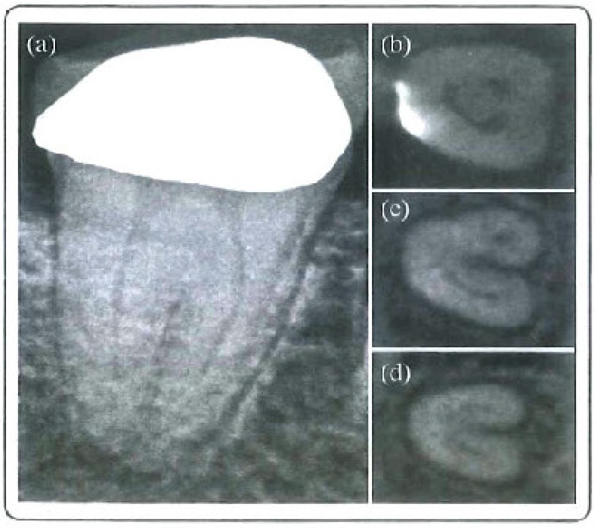


Fig. 29 Preoperative periapical radiograph of a mandibular right second molar (a) with corresponding axial CBCT slices captured from the coronal third (b), mid-root (c), and apical third (d) demonstrating a C-shaped external root form and C-shaped internal root canal configuration.

- *Dental periapical pathosis:* CBCT showed significantly more findings including expansion of lesions into the maxillary sinus, sinus membrane thickening, and missed canals. The generally higher detection rates afforded by CBCT may be of clinical importance in patients who present with pain or who have poorly localized symptoms associated with an untreated or previously root treated tooth with noevidence of pathology identified by conventional imaging Fig. (30).

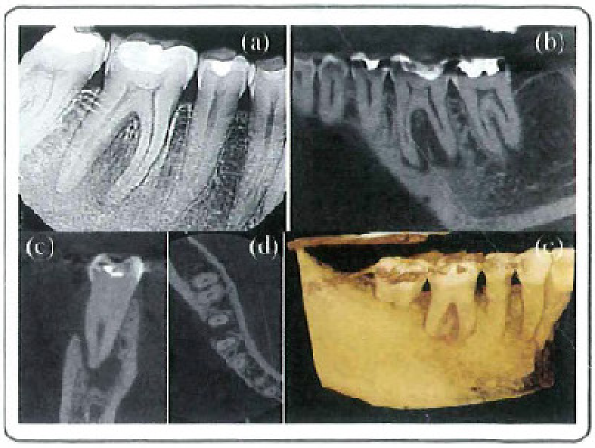


Fig 30 A patient was referred for evaluation and treatment of tooth number 30. Patient presented with pain to percussion and no response to cold testing. Periodontal probing depths were WNL. Root canal therapy was indicated based on 2D radiographic fi ndings and clinical tests (a) Periapical radiograph of tooth number 30. (b) is a sagittal view of tooth number 30. A periapical radiolucency involving both mesial and distal roots as well as the furcation was detected. The lingual bone is still intact which gives the impression of greater bone volume and density in the furcation in the periapical (2D) radiograph than is actually present. (c) Coronal view of the distal root demonstrating complete loss of buccal bone. Due to the tight gingival attachment, periodontal probing was WNL. (d) Axial view demonstrating buccal plate perforation that cannot be detected from the 2D radiograph. (e) 3D reconstruction demonstrating the actual endo-perio defect. Considering the unfavorable prognosis for resolution of the extensive endo-perio lesion, extraction was recommended

- *Root fracture:* as they are difficult to diagnose accurately using conventional radiography Fig. (31).

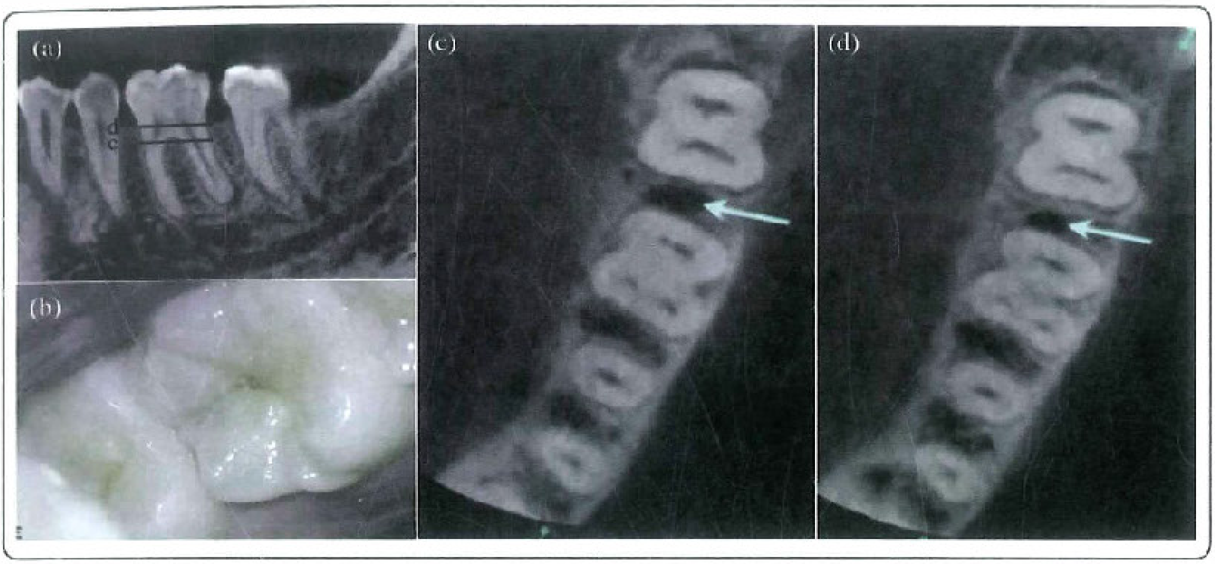


Fig 31 Patient presented for evaluation and treatment of tooth number 19 The chief complaint was pain on biting and sensitivity to hot drinks. Clinical findings no response to cold and positive response to bite stress testing. A diagnosis of a necrotic pulp and symptomatic apical periodontitis was established. The presumed etiology was extension of a distal marginal ridge crack. (a) Sagittal view of tooth number 19 showing a distal root periapical radiolucency. The lines on the sagittal view correspond to the axial section views (c) and (d). (b) Clinical image (occlusal view) demonstrating the distal marginal ridge crack. Axial views (c) and (d) demonstrate the distal bone loss associated with the fracture (blue arrows) and unfavorable prognosis

- *Root resorption:* CBCT has been used successfully to confirm the presence of IRR and differentiate it from ERR Fig. (32).

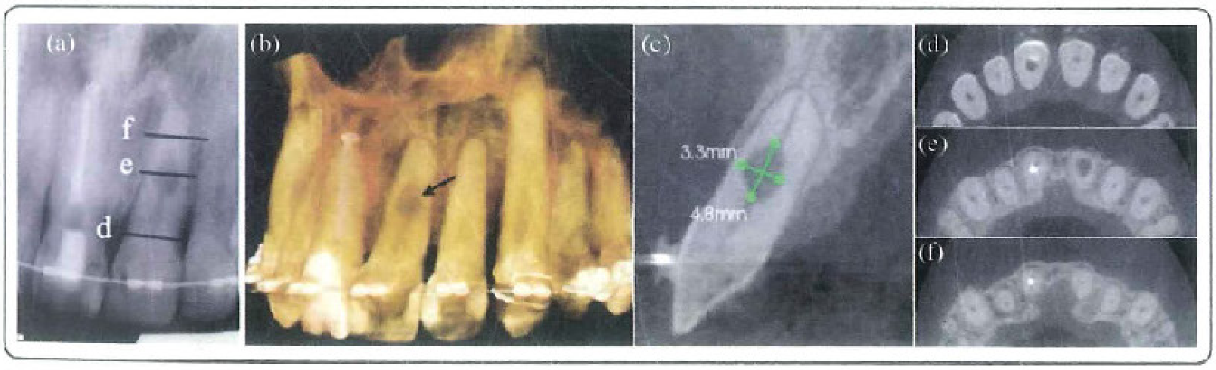


Fig 32 Patient was referred for evaluation and treatment of an internal resorptive defect on tooth number 9 (a) Periapical radiograph of tooth number 9. The 3 lines correspond to the axial section views in (d), (e), and (f). (b) 3D reconstruction of maxillary anterior teeth demonstrating the internal resorptive defect (black arrow). (c) Sagittal view of tooth number 9 with the 3.3 × 4.8 mm measurement of the defect. (d), (e), and (f) are axial views of tooth number 9 Note the normal canal anatomy coronal and apical to the defect (d , f). The maximum width of the defect is demonstrated in axial view (e)

2. *Postoperative assessment.*

- Monitoring the healing of apical lesions which is an important aspect of postoperative assessment in endodontics.
- As adequacy of root canal obturation is an important determinant of endodontic success, it might be considered that CBCT is used in the initial and subsequent monitoring of the integrity of root canal fillings.
- Endodontic surgery is often complicated in the posterior teeth by their proximity to anatomical structures. The mandibular teeth can be close to the mandibular canal while maxillary molars are often close to the maxillary sinus. CBCT imaging provides several advantages for preoperative treatment planning especially in maxillary posterior teeth with apical pathology Fig. (33).

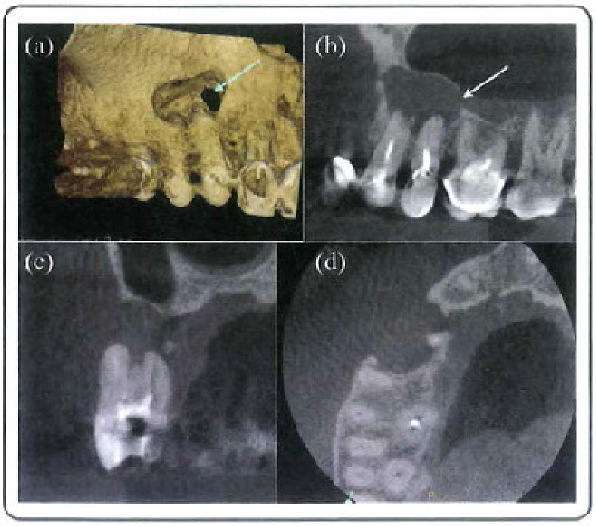


Fig. 33 CBCT 3D rendering of teeth #12 and #13 referred for periapical surgery (a). Perforation of the maxillary sinus can be visualized (blue arrow). Sagittal view of teeth #12 and #13 (b). Perforation of the maxillary sinus noted (white arrow). Coronal view of tooth #12 demonstrating the through-and-through nature of the periapical defect (c). Axial view demonstrating the mesiodistal extent of the periapical defect (d)

Micro-computed tomography

The X-ray micro-computed tomography (micro-CT) was developed in the early of 1980s . The micro-CT is a noninvasive and non-destructive method to obtain two- and three-dimensional images .Its operation is based on multiple X-ray converging on the sample and captured by a sensor. The projected X-ray is converted into digital images.

Micro-CT present several advantages in comparison with other methods, but otherwise has some limitations. Scanning electron microscopy, stereomicroscopy and confocal laser microscopy can be used for superficial analysis but do not provide 3D images without the requisite of sectioning the samples. Contrary of these microscopic methods, micro-CT allow the use of the same sample for different tests without destruction of the sample. This characteristic is very important particularly when it is required to evaluate volume pre and post instrumentation, quality of root canal obturation or removal of the material from root canal (retreatment). Other advantages of micro-CT are the possibility of repeated scanning and the manipulation of image using specific software. On the other hand, a limitation of micro-CT is the impossibility of using for in vivo studies due to the radiation level of exposure. Moreover, micro-CT permits the examination of specimens of limited size, which restrict some analysis. Instead, cone beam computed tomography (CBCT) could be used in patients despite its lower resolution.

Some applications of micro-CT in endodontic research include the analysis of internal anatomy of teeth,instrumentation of root canal , root canal fillings, retreatment, physical and biological properties of materials.

Nano-computed tomography

The introduction of nanofocus® tubes increases the image quality of radiographic images further more. By using these high resolution tubes in Computed Tomography a

further increase of quality regarding spatial resolution is possible. In microCT resolutions in the μm-scale are state of the art. Resolutions in the sub micrometer scale have been dedicated to synchrotron technique. The introduction of high resolution nanofocus® -tube technology allows focal spot sizes below one micrometer. Therefore the resolution of CT-systems equipped with such high resolution nanofocus® -tubes could be further increased. So called nanoCT® -Systems are pushing forward into application regions which have been exclusive to expensive synchrotron technique so far.

Chapter review Questions

1. Discuss the importance of radiographs in endodontics
2. Discuss the basic radiographic technology.
3. Differentiate between endodontic and nonendodontic lesions.
4. Point out the importance of digital imaging in endodontics.
5. Review utilization of cone beam computed tomography in endodontic diagnosis
6. Describe the impact of cone beam computed tomography in treatment planning

References

- Walton RE, Torabinejad M. Principles and Practice of Endodontics, W.B. Saunders company, 4th edition 2009.
- Cohen S, Burns R C. Pathways of the pulp, Mosby, 10th edition 2011
- Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics, BC Decker Inc, 6th edition 2008
- Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: Part 1. Conventional and alternative radiographic systems. International Endodontic Journal, 2009; 42:447-462.
- Nair MK and Nair UP. Digital and Advanced Imaging in Endodontics: A Review. J Endod,2007; 33: 1-6.
- Mavridou AM, Pyka G, Kerckhofs G, Wevers M, Bergmans L, Gunst V, Huybrechts B, Schepers E, Hauben E, Lambrechts P. A novel multimodular methodology to investigate external cervical tooth resorption. Int Endod J. 2015 Mar 26.
- Mohamed I. Fayad and Bradford R. Johnson. 3D Imaging in endodontics. A new era in treatment and diagnosis. Springer International Publishing Switzerland 2016.
- Villas-Bôas MH, Bernardineli N, Cavenago BC, Marciano M, Del Carpio-Perochena A, de Moraes IG, Duarte MH, Bramante CM, Ordinola-Zapata R. Micro-computed tomography study of the internal anatomy of mesial root canals of mandibular molars. J Endod. 2011 Dec;37(12):1682-6

5

Pain and Differential Diagnosis of Orofacial Pain

Khaled M. Ezzat

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define pain and pain threshold.
2. State pulp nerves and nerve impulse mechanisms.
3. Describe the role of odontoblast in pain perception.
4. Discuss different theories of pain transmission.
5. Describe the clinical applications of Gate control theories.
6. Demonstrate the theories of pulpodentinal pain fiber excitation and it's clinical applications.
7. Apply the effect of intrapulpal blood pressure and it's relation to pain stimulation.
8. Describe odontogenic pain, it's different types and how to differentiate between acute and chronic pain.
9. Describe how non odontogenic pain mimic endodontic pain.
10. Discuss periapical pain both acute and chronic.

Postgraduate students should be able to

1. Analyze pain and pain threshould.
2. Distinguish pulp nerves and relate nerve impulse mechanisms.
3. Illustrate the role of odontoblast in pain perception.
4. Analyze different theories of pain transmission.
5. Criticize the clinical applications of Gate control theory.
6. Analyze the theories of puplodentinal pain fiber excitation and it's clinical applications.
7. Illustrate odontogenic pain, it's different types and how to differentiate between acute and chronic pain.
8. Argue how non odontogenic pain mimic endodontic pain.

Chapter Outline

Definition of pain
Reduction of stimulus level
PULP NERVES:
- Nerve cell
- Nerve impulse

Theories of pain transmission
- Specificity theory
- Pattern theory
- Gate control theory

Theories of Pulpodentinal Pain Fiber excitation
- Dentin innervation
- Hydrodynamic Theory
- Dentinoblastic deformation or injury (Transduction)
- Body self Neuromatrix Theory

Current flow Theory
Odontogenic pain
- Dentinal pain
- Pulpal pain

Non-odontogenic pain
Periapical pain

According to the Dornald's Medical Dictionary, pain is defined as; a more or less localized sensation of discomfort; distress or agony resulting from stimulation of specialized nerve endings.

Nociception; it is the phenomenon of sensation to tissue injury. So nociception is what you feel and pain is the sensation of what you feel.

Definition of pain:

It is emotional experience usually triggered by nociception input into CNS and manifested by conscious and autonomic reaction.

- The motor reaction of the patient may be jerking heads, closing mouth,extension of arms and legs and violence reactions.
- The autonomic reaction appears as increase in blood pressure, increase heart rate and sweating.
- The psycological reactions may be manifested as crying, fear, agony and screaming.

So we can conclude that nociception could be present without pain, when increased pain threshold, and pain could be presented without nociception as, emotional state, personality, past experience and motivational influences are major factors in localizing and interpreting pain modularity.

Pain threshold can be classified into three main categories:

1- Sensory threshold: the lowest level of stimuli that will cause any sensation;touch, temperature and vibration.
2- Pain threshold: the lowest level stimuli that cause the subject to report pain.
3- Pain reaction threshold: the amount of pain that could be tolerated after pain is first perceived.

Reduction of stimulus level

There are three methods that could be used to reduce the stimulus level of pain perception.

1- *Psychological factors* can modify and reduce pain perception by informing the patient especially sensory about what expected before, during and after treatment. Instructions how to relief pain and frequent interpersonal contact to reinforce motivation and support are important.
2- *Pharmacological control* of pain could be achieved by administration of general or local anesthesia, analgesics for pain and muscle tension and sedation that enhance relaxation.
3- *Stimulation-produced analgesia* (counter irritation): Chemicals, cauterization, mechanical devices, massages, temperature, needles and electrical stimuli were used to initiate endogenous opiates-endorphins and enkephalines produced by the brain and substantia gelatinosa, affect the descending pathway and anterior pituitary gland.

   The action may be through the stimulation of A-delta fiber,closes the gate for C-fibers and the increase of endorphins production.

PULP NERVES

There are three types of pulp nerves; large, intermediate and small; the larger the diameter the faster the conduction.

1 Larger myelinated:

   A-alpha: Carry touch and pressure.

   A-beta: Carry proprioception and vibration.

   A-gamma: Mechanoreceptors.

   A- delta: carry pain and temperature.

2- Intermediate (Efferent) = B fibers.

3- Smaller unmyelinated C fibers:
   Transmit pain and temperature.

Table (1) Nerve fibers in the pulp

	A- DELTA FIBERS	C- FIBERS
Terminals	Dentinoblast and subdentinoblastic	Near blood vessels
Pain	Sharp, pricking, but bearable	Throbbing, aching, less bearable
Stimulus	Stimulated without injury electric, cold and hot (vitality)	High threshold pain with inflammatory process (delayed)
Hypoxi	Short survival in presence of pulp necrosis	Longer survival in presence of pulp necrosis

Nerve cell:

Each nerve cell consists of a central portion containing the nucleus, known as the cell body, and one or more structures referred to as axons and dendrites. The dendrites are rather short extensions of the cell body and are involved in the reception of stimuli. The axon, by contrast, is usually a single elongated extension; it is especially important in the transmission of nerve impulses from region of the cell body to other cells.

The nerve impulse:

The nerve impulse is dependent on:

1- Change in the permeability of neural membrane.

2 Sodium potassium pump mechanism.

The resting potential of the nerve:

- The polarized nerve membrane have a positively charged sodium ions (NA++) more concentrated in the extracellular tissue fluid than in the cytoplasm. At the same time potassium (K++) ions are concentrated inside the cytoplasm than in the extracellular fluid.
- Stimulation of the nerve membrane increases permeability of positively charged sodium ions to penetrate into axons. Leads to momentary depolarization at the point of stimulation.

As impulse moves, the membrane is recharged by outward migration of K++ions. Subsequently the sodium pump expels the Na+ ions into the extracellular fluid, while the potassium pump returns the K++ ions to intracellular fluid. o, the resting potential is now restored.

The cycle repeats itself as a self propagating wave of the action potential or action current till it reaches the synaptic terminal.

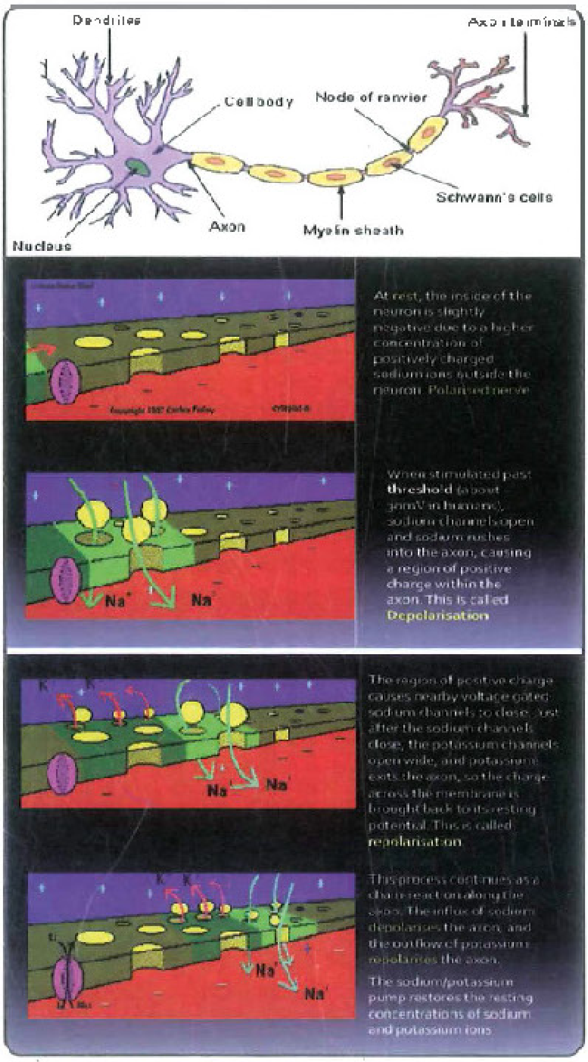


Fig. 1. Neuron; the basic unit and the mechanism of self-propagating waves of depolarization along the nerve.

The receptors must build up enough electrical activity until it finally reaches the nerve fiber threshold. Then suddenly an action potential is set off in the neuron terminal.

Pain Mechanism:

An effective approach to differential diagnosis must be based on an understanding of pain mechanism. It can be simply explained such that; the noxious stimuli activate the pain receptors which in turn sends a nerve impulse to the spinal nucleus in the trigeminal ganglia, that in turn reaches the thalamus to the post central gyrus of the cerebral cortex leading to stimulation of the glands and the muscles. Prolonged muscle contraction leads to ischemia and accumulation of pain producing substances.

Role of dentinoblast in pain transmission

- The cell body and the process are in close contact with the nerve terminals (receptors).
- Stimulation of such cells may release a neurotransmitter substance that alters the permeability of the nerve endings.

Mechanical deformation of dentinoblast acts as transducer mechanism converting mechanical energy into electrical energy.

So, dentinoblast and A-delta nerve terminal function together as intradental sensory units and considered as a peripheral sensory capsule.

Theories of pain transmission

1- Specificity theory: This theory is explained as different sensory fibers mediate different sensory modalities such as; pain, heat, cold, touch and pressure. The receptors for pain are specific and mostly unmyelinated free nerve endings. When stimulated, these fibers transmit impulses along specific pathway.

2 Pattern theory: Pain is generated by nonspecific receptors. All nerve fiber endings are alike and pattern of pain is produced by a more intense stimulation than for other sensations. The summation of pain impulses produces a pattern that the brain receives and recognizes.

3- Gate control theory: The gate control theory combines and extends previous central summation theories. This theory excludes the need for specialized nociceptive afferents to explain pain sensations. However, high threshold afferent nerves do exist and can be incorporated into the hypothesis without weakening its value in explaining central processing.

As a theory rather than a law, gate control has provided a continuing framework for investigation.

- There are two factors regulating the transmission of pain:
- Gating mechanism in the gray matter of the spinal cord called Substantia gelatinosa. This receives the painful impulses (sensory afferent) from the peripheral nerves and permit their passage to the brain by opening the gate, or prevent their passage by closing the gate. Opening and closing the gate depends on the speed of the impulse (the larger the fiber the greater the speed) and the interaction between noxious pain stimuli transmitted along smaller fibers and those stimuli of touch and pressure, that are transmitted along large fibers.
- Descending central control from the intense brain mechanism. This modulate the gating mechanism from emotional, motivational, psychic, peripheral and visceral as well as from past experiences.

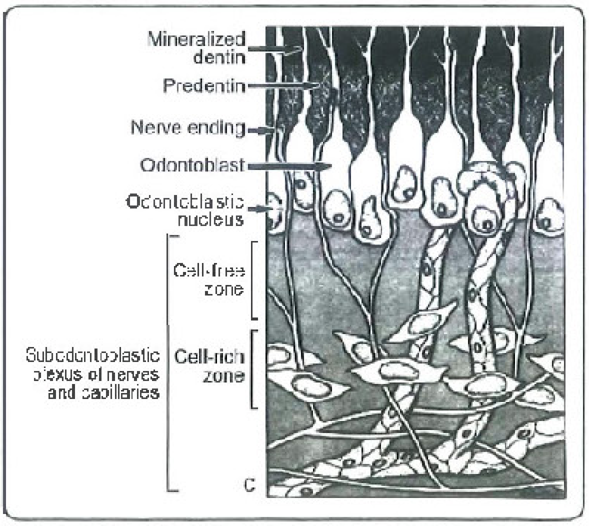


Fig. 2.Peripheral layers of the Pulp.

How The Gate Works

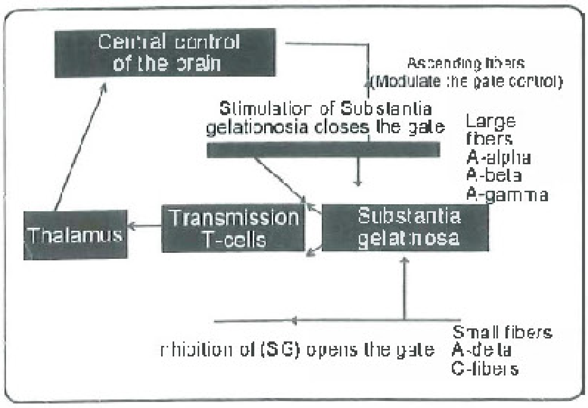


Fig. 3. Diagrammatic representation of the gate control theory of pain.

- Afferent neurons (A alpha, beta and gamma) enter the spinal cord via dorsal root;synapse with T-cells. Collateral branch enters (SG) and another branch ascends to higher center. Larger diameter fiber can only excite the SG cells, which in turn inhibits impulses to T cells so the gate is closed. Large diameter axons can also send collateral branches at higher centers of brain. Intern descending tracts of the brain can influence(modulate) the gate control.
- Afferent small fibers (A delta and C fibers); synapse with T-cells and terminate in (SG). Impulses from small fibers can only inhibit SG cells, stopping them from inhibiting impulses to T-cells, so opens the gate.
- SG sends branches to synapse with incoming afferent fibers entering T-cells. Presynaptic inhibition, the only action is to inhibit impulses to T-cells.

Gate control may be further modulated by intrinsic brain mechanism and through emotional, motivational, peripheral, psychic as well as past learned experience.

Its basic principles are as follows:

1- Incoming afferent nerve activity is modulated by a gating mechanism in the dorsal horn of the spinal cord and brain stem. The gate either inhibits or facilitates the activity of the transmission of T-cells that carry activity farther along the nervous pathway.

2- The gate is affected by the relative degree of activity in larger diameter A beta fibers and small A delta and C fibers.The large diameter A beta fibers are activated by non-noxious stimuli, and the small a-delta and C fibers by noxious stimuli. Large fiber activity tends to close the gate,whereas small-fiber activity opens it.

3- Descending control mechanisms from the higher levels in the central nervous system are influenced by emotional, motivational and past affective processes. The higher level mechanisms also modulate the gate. Activity in large afferent fibers not only tends to close the gate directly but also activates the central control mechanisms, which also close the gate.

4- When the gate is open and activity in the incoming afferents is sufficient to activate the transmission system, two main ascending pathways are activated. One is the sensory discriminative pathway, which connects to somato sensory cortex by way of the ventroposterior thalamus. This pathway allows the localization of pain. The second ascending pathway involves the reticular information through the medial thalamic and limbic system, which deals with the unpleasant, aversive and emotional aspects of pain. Descending pathways, as well as acting on the dorsal horn gate may also interact with these two ascending systems.

- **Clinical Application of Gate Control Theory**
- *Spontaneous pain*: If A-beta fibers are not stimulated, pain is a result of C fiber and A-delta fibers. An example, during cavity preparation the smaller fibers produce the pain as A-beta fibers are few at the periphery.
- *Intermittent pain*: In case of pulpitis, if A-beta fibers deeper in the pulp are stimulated, they close the gate to pain from the C-fibers.

Conversely, if A-beta fibers are not activated by inflammatory process,the C-fibers can cause pain. Alteration of both in case of pulp inflammation closes and opens the gate, this explaining intermittent and spontaneous pain.

- *Pulpal anoxia* (hypoxia): Oxygen deficiency in diseased pulp would affect the larger fibers first, so gates remain open. Stimuli that were not noxious to normal pulp such as hot and cold, could trigger a more painful response because the small fibers have longer survival time in absence of oxygen.
- *Counter irritation and pressure:* Pressure and massage will excite the A-alfa fibers present in the skin, so closes the gate to pain. An example for this, pressing firmly against the anterior border of the ramous before inserting the anesthetic needle will close the gate for pain. Again, continuous rotation of the acupuncture needle stimulates the peripheral nerve A-alfa fibers to activate the substantia gelatinosa(SG) to close the gate for pain.
- This theory has been widely accepted, but it leaves unanswered questions, such as chronic pain issues, sex based differences and the effects of previous pain experiences.

Theories of Pulpodentinal Pain Fiber excitation

Three theories of pain transmission have been proposed:

1- Dentin innervation

2- Hydrodynamic Theory.

3- Dentinoblastic deformation or injury (Transduction).

4- Body-self neuromatrix theory.

1- Dentin Innervation

There are nerve fibers within the dentinal tubules that, when injured, initiate the nerve impulse (action potential). The nerve and dentinoblastic processes are intertwined in a corkscrew pattern and therefore it is extremely difficult to detect.

2- Hydrodynamic Theory

The nerve endings in the subdentinoblastic, dentinoblastic zones and in the tubules of inner dentin are sensitive to sudden pressure changes, fluid movement inside the dentinal tubules leads to mechanical deformation of the nerve membrane.

Fluid in the dentinal tubules comes from the intercellular fluid of the pulp connective tissue. Movement of the fluid either pulpward or outward, exerts a direct mechanical deformation on the low threshold A-delta free nerve fibers within the tubule or in the adjacent pulp tissue. The lost fluid is immediately replaced by pulpal tissue fluid responded to the capillary force within the dentinal tubule. The fluid movements also cause movement of dentinoblasts, which in turn deform the nerve fiber in contact with their processes or cell body. The deformed nerve membrane increases permeability to positively charged sodium ions in the neural membrane, which in turn leads to depolarization the A-delta fiber membrane and action potential (pain impulse) is initiated.

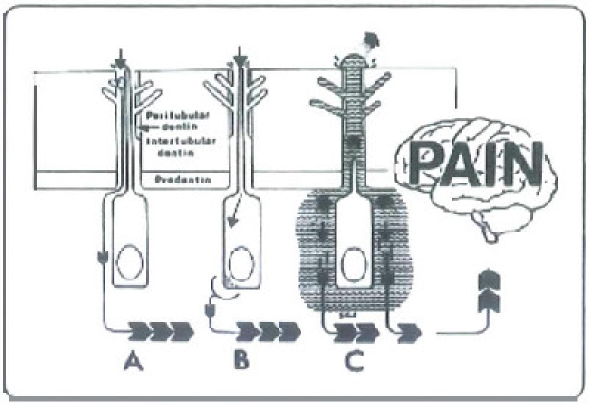


Fig. 4. Effect of air blast on exposed dentinal tubules.

Clinical Applications:

- Frictional heat, frictional stresses, pressure of chiselling and air blast, cause fluid loss, which immediately replaced by pulpal tissue fluid. Dentinoblast and nerve terminals maybe also aspirated into tubules,evoking a painful response.

- Sugars and hypertonic solutions, create an osmotic gradient, causing fluid movement from deeper tubular area of lesser concentration resulting in loss of fluid. The first reaction is firing first, the A delta fiber and result in sharp pain. If the inflammation is present in the subjacent pulpal tissue,a dull persistent pain may follow as a consequence to activation of higher threshold C-fibers.
- Pain with thermal stimulation; as fluids have a coefficient of thermal expansion ten times greater than that of tubule wall so,
  * *Cold*: In normal tooth cold causes contraction of the fluid and its outward flow whether the tubule is opened or closed, so pain is not due to intrapulpal blood pressure. In acute pulpitis, cold may not exacerbate response as; A-delta fibers are not viable.
  * *Hot*: Heat causes expansion of the fluid either towards the pulp in case of closed dentinal tubules or away from the pulp if the tubules are opened. Heat in normal tooth after longer duration is duller and longer because of the activation of deeper C fibers.

N.B.: Cold stimulus is faster than hot, as with heat larger volume of dentin must be affected before dislocation of the tubule content is produced.

3- Dentinoblastic deformation or injury (Transduction)

Dentinoblast can be injured by any stimulus applied to dentin, thermal, mechanical, chemical or osmotic. When dentinoblast are injured or deformed, they may produce stimuli that are received by the free nerve endings within the tubules or in contact with any part of the dentinoblast. Dentinoblast injury may transmit pain through:

1- Chemoactivation; chemicals released by injured tissues.
2- Electroactivation; changes the surface electrical potential of the neuralmembrane.
3- Mechanoactivation; movement associated with dentinoblast deformation.

4- Body-self neuromatrix theory

In 1999 Melzack and Wall came up with a newer theory of pain that answered some of these questions. This "new" theory proposes that pain is a multidimensional experience produced by characteristic neurosignature patterns of nerve impulses generated by a widely distributed neural network-the body-self neuromatrix on the brain.

The theory stated that every human being has an innate network of neurons that they named the "body-self neuromatrix". Each person's matrix of neurons is unique and is affected by all facts of the person's physical, psychological condition & by their experience.

Acute pains evoked by brief noxious inputs have been meticulously investigated by neuroscientists, and their sensory transmission mechanisms are generally well understood.

In contrast, chronic pain syndromes, which are often characterized by severe pain associated with little or no discernible injury or pathology, remain a mystery. Furthermore, chronic psychological or physical stress is often associated with chronic pain, but the relationship is poorly understood. The neuromatrix theory of pain provides a new conceptual framework to examine these problems. It proposes that the output patterns of the body-self neuromatrix activate perceptual, homeostatic, and behavioral programs after injury, pathology, or chronic stress. Pain, then, is produced by the output of a widely distributed neural network in the brain rather than directly by sensory input evoked by injury, inflammation, or other pathology.

The neuromatrix, which is genetically determined and modified by sensory experience, is the primary mechanism that generates the neural pattern that produces pain. Its output pattern is determined by multiple influences, of which the somatic sensory input is only a part, that converge on the neuromatrix.

Effect of Intrapulpal blood pressure

Van Hassel; reported that the tissue fluid pressure in the pulp 10mm Hg. Slight increase in the intrapulpal blood pressure to 13mm Hg causes reversible inflammatory condition. Increased pressure to 35mmHg, induces irreversible state due to collapse of thin walled veins and venules, that leads to localized vascular stasis, ischemia and local cellular death. This cycle repeats itself corono-apically.

Heat stimulation: Heat application leads to vasodilatation in the pulpal blood vessels that leads to increase in the intrapulpal blood pressure.Intact tooth; specific pulpal temperature must be reached before there is pain.Tooth with inflamed pulp; an increased intrapulpal pressure already exist, this leads to immediate pain to gradual or sudden temperature rise.

Cold stimulation: In case of normal tooth, pain due to concentration of the dentinal fluid (Hydrodynamic theory). In case of acute pulpitis, cold may not exacerbate painful response, as peripheral A-delta receptors are not vital. Cold relief pain as it decreases intrapulpal blood volume so; vasoconstriction action will decrease intrapulpal blood pressure below threshold level of viable C-fibers.

Current flow theory

Pain with sour, fruit juices, sugars, salt and dissimilar metals; may be due to current flowing between oral cavity (positively charged) and pulp (negatively charged). Any electrolyte that upsets the ionic balance results in current stimulus to the nerve endings of the dentinoblasts.

Odontogenic pain:

Odontogenic pain may originate from the pulp and or periapical tissues. Pain originating from each of them is perceived differently. In most cases, the diagnosis of dental pain is relatively straight forward. The history describes a consistent, logical pattern of symptoms. The patient indicates a particular tooth, which, when examined,reveals a diseased pulp or periradicular tissues and when stimulated, appropriately reproduces the significant symptoms described in the history. Any departure from this pattern should alert the dentist to be extra cautious in formulating a diagnosis and treatment plan.

There are two types of pulpal diagnosis; those based on clinical findings and those based on histologic findings. Clinical signs, symptoms and diagnostic tests do not,in many cases, correlate with the true histopathologic status of the pulp. Clinically the pulp can be diagnosed as healthy; damaged but able to repair (reversible condition) or damaged beyond repair (either irreversible pulpitis or necrosis). Histologically, pulpitis is described as acute, chronic, or hyperplasic. The dentinal sensitivity should be distinguished from pulpal inflammation. Therefore, we are going to explain the difference between the two conditions.

Dentinal pain

This dentinal pain could be referred to as hypersensitivity, hyperemia, or reversible pulpitis. Dentin sensitivity is probably a symptom complex, rather than a true disease; these terms describe a specific condition that pain is arising from exposed dentinal tubules. Pain is poorly localized. The pain is consistent with an exaggerated response of the normal pulpodentinal complex, and it is severe and sharp on application of the stimulus to the exposed dentin. However, symptoms disappear immediately after removal of the stimulus.

Pain is intensified by:

- Air blast causes evaporation of the dentinal fluid, pain evoked by hydrodynamic theory.
- Dental drill; results in movement of dentinal fluid as a result of pressure and heat also, there is decrease in intrapulpal blood pressure (IPP) after 25 seconds to 10mmHg and rise above the original base increase pain (hyperemia).
- Cold stimulation results in contraction of the dentinal fluids and decrease in IPP. (Hydrodynamic theory)

- Hot stimulation results in increase in IPP and the difference in coefficient of thermal expansion between fluids and dentin (Hydrodynamic theory).
- Sweet and sour evoke pain by electric current (current flow theory) and the dehydration of dentin (hydrodynamic theory).

Scanning electron microscopic studies show that hypersensitive dentin has more than seven times the number of surface tubules than insensitive dentin. Although dentinal tubules of insensitive teeth are occluded, the apertures of the dentinal tubules in hypersensitive dentin are opened or widened. When examination of the tooth reveals the presence of exposed dentin the diagnosis is dentin hypersensitivity.

Reversible pulpitis implies that from the clinical sign and symptoms, and diagnostic tests, the pulp is vital and inflamed but possesses the reparative capabilities to return to health on removal of irritant. However, in the presence of etiologic factor such as; caries, fractures, erosion of cervical tooth structure, defective restoration, recent restoration, as well as periodontal disease, a diagnosis of reversible pulpitis is appropriate. Radiographic findings may show; caries, defective restoration, and no periapical changes.

Pulpal Pain

The pulp is enclosed in a rigid, mineralized environment and has avery limited ability to increase its volume during episodes of inflammation. In this low compliance environment, an intense inflammatory response can lead to adverse increase in tissue pressure, outpacing the pulp's compensatory mechanisms to reduce it. The inflammatory process spread circumferentially and incrementally through the pulp, perpetuating the vicious cycle of pulpal inflammation. The pain in this case persists after removal of the stimuli.

1) Acute <u>pulpalgia (pulpitis)</u>: true pulpalgia begins with development of pulp inflammation or pulpitis. In the presence of inflammation, the response is exaggerated, which is often thermal.

Hyperalgesia, is one of the classic symptoms of irreversible pulpitis, lingering pain from thermal stimuli. Pain is poorly localized; it ranges between explosive, intermittent, throbbing and boring pain. The cause of pain with hot food or drink is due to the increase in the intrapulpal blood pressure. Cold, sweet and sour and sometimes chewing intensify pain due to hydrodynamic theory and current flow theory. With provocation, an injured vital pulp with local inflammation can emit symptoms of A-delta fiber pain, as the exaggerated A-delta fiber pain subsides, a dull, throbbing pain may persist. This second pain signifies the inflammatory involvement of C nerve fibers. Associated signs are deep caries and extensive restoration. Radiographically; deep caries and deep restoration with no secondary dentin, none or early periradicular changes in advanced conditions.

Acute pulpitis may be classified into three categories according to the signs and symptoms as follow:

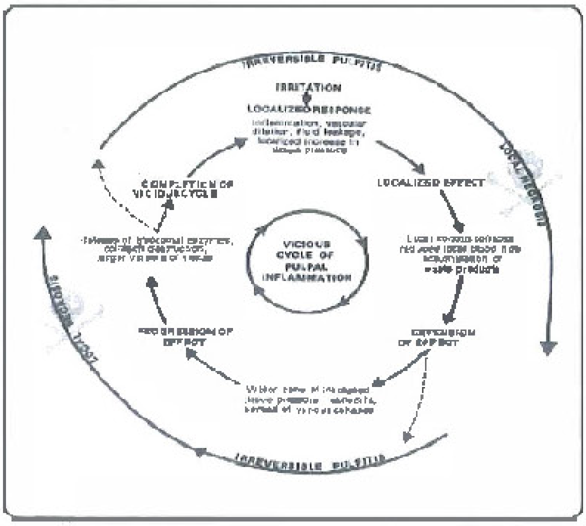


Fig. 5. Vicious cycle of pulpal irritation and inflammation.

a- *Incipient acute pulpalgia:* it is a reversible condition usually follows cavity preparation or traumatic occlusion. The pain intensity may range from mild to moderate and disappears on the next day. Pain is evoked by cold stimulus and sugar in a carious lesion. Histologically, extravascular migration of

inflammatory cells, indicating a reversible condition. Vitality test gives positive response with cold application. The treatment of this case is the removal of the cause, followed by sedative cement base.

b- *Moderate acute pulpalgia:* it is an irreversible condition; pain is nagging or boring and persists after removal of the stimulus; as C-nerve fibers are stimulated by inflammatory process. Spontaneous(unprovoked) pain is another hallmark of irreversible pulpitis. Pain may go aching for minutes, hours, or days. At first pain could be localized by the patient. If the pulpal pain is prolonged and intense, central excitatory effects may produce pain referral to a distant site or other teeth. When C-fiber pain dominates A-delta fiber pain, pain is more diffuse and the dentist's ability to identify the offending tooth is reduced. Pain increases with cold(hydrodynamic theory), hot food and drink, sucking the cavity and biting. Spontaneous pain with lying down, or any act that raises the cephalic blood pressure. The tooth responds sooner to cold application.

c- Probing, and sometimes percussion duplicate pain.

d- *Advanced acute pulpitis:* in this stage, pain is the most excruciating acute pain. Spontaneous severe pain relieved by cold (hot tooth).Occasionally the inflamed vasculature is responsive to cold, which vasoconstrict the dilated vessels and reduces tissue pressure. Momentary relief from the intense pain is provided. Relief provided by a cold stimulus is diagnostic and indicates that a vital irreversible inflamed pulp is becoming increasingly necrotic.

2) Chronic pulpalgia:

Pain in chronic pulpalgia is mild, as pulp shows degeneration, it may last for months or years. Pain is diffuse and may be referred; it is due to increase in intrapulpal blood pressure. Hot drinks, lying down and airoplane flight evoke pain. Patient cannot localize the tooth. Pain is not affected by cold, appears in eating. Examination of the tooth reveals large carious lesion, fractured amalgam restoration, recurrent caries under filling (inlay). Pulp testing with Co^2 ice, gives response at highest level. Radiographically; thickened periodontal membrane, condensing osteitis at the apices of the roots may be present, and disappear after removal of the cause. External root resorption may also be seen.

Chronic pulpitis may also present other forms of pulpal diseases or conditions that lead to chronic pain such as:

- *Hyperplasic pulpitis:* manifested by the presence of hyperplasic pulp; tissue erupts out of an opened carious cavity. It is symptom free unless stimulated directly by compressing food against the cavity, and extreme hot and cold. Pulp polyp may be lifted from the cavity, it is mildly painful.
- *Pulp necrosis*: pulp necrosis has no symptoms. Partial necrosis maybe confused with chronic pulpalgia. In multirooted teeth, the pulp in a canal may be vital, whereas the other is necrotic (confusing results).Clinical examination reveals no response with pulp tester or slight response at highest level, due to some viable C -nerve fibers as it has a long survival in the presence of hypoxia. Tooth may be slightly painful for percussion.
- *Internal resorption:* pain symptoms similar to moderate acute pulpalgia. When present in the crown it is called pink spot, if the pulp has broken via the external tooth surface it erupts in the oral cavity similar to hyperplasic pulpitis. Root resorption could be diagnosed radiographically.
- *Traumatic occlusion:* bruxism or hyperocclusion are the causative factors. Tooth responds as mild pulpalgia, tooth is sensitive to cold, and pain appears after awaking. The vagueness of the pain is most important. Electrical and thermal test responds like normal or hyperplasic tooth. In diagnosing such a case, if one suspect's pain from trauma, one should look for facets

of wear on the tooth. If confusion between it and pulpitis exists, occlusal adjustment is done first, if no relief of pain, so it is pulpitis.

- *Incomplete fracture or split tooth:* (cracked, tooth syndrome) consists of an incomplete fracture of a tooth with a vital pulp Symptoms range from constant, unexplained toothache to hypersensitivity. Hypersensitivity with mastication results in a quick unbearable stab as cusp is separated from the remainder of the tooth If the split has extended through the pulp, bacterial invasion occurs and true pulpitis results. Patients complain that tooth is painful to bite on, varied patterns of referred pain and sensitivity to thermal changes. The most common symptom is sharp pain that occurs upon release of chewing pressure. Percussion of the tooth, careful probing with explorer, and biting on a tooth slooth facilitate diagnosis.

Nonodontogenic pain:

Many conditions mimic endodontic symptoms. The most common nonodontogenic conditions that may imitate acute endodontic symptoms will be reviewed briefly. However, there are distinct clinical features that will characterize the condition as nonodontogenic. Care must be taken that definitive dental treatment is not initiated until all doubt has been resolved as the origin and cause of pain.

Toothache of neurovascular origin. This includes a group of pain disorders that have common mechanisms involving the trigeminal neurovascular system. The most common type of pain is migraine headache. Migraine pain can be referred to the teeth. Asthe toothache occurs in conjunction with one of the common forms of neurovascular headaches, diagnosis is rarely a problem. Importantly, the toothache subsides when the headache symptoms subside. Some migraine variants are more of diagnostic problem. For example, neurovascular variants, or migrainous neuralgias, can produce toothache without traditional headache complaint. The pain is similar to that with irreversible pulpitis. Spontaneous, variable, and throbbing. However, the neurovascular toothache is characterized by periods of remission, and exacerbations over months and years, and there is a lack of reasonable dental cause for the pain.

Toothache of neuropathic origin. These types of pain may be either episodic or continuous. The patient uses words not associated with odontogenic pathology (e.g., burning, electric-like, tingling).

a- **Episodic neuropathic toothache** spontaneous, severe, sudden, sharp, lancinating, electrical shock pain that is felt in the tooth or radiates. The pain lasts for seconds to minutes, and then it disappears. It is consistent with trigeminal neuralgia, which occurs between the 5th and 8th decades of life and causes distress for the patient. The most prominent feature of episodic neuropathic toothache is the existence of trigger point. These are often located in the skin of lips, cheeks, or gingiva when touched, they provoke a painful response. Nevertheless, the possibility that these symptoms are being triggered by pulpal pathosis must be ruled out. To differentiate these attacks, the period of remission is also free from the thermal and periapical sequelae seen in genuine endodontic pathosis. Un-fortunately, anesthetic blocking arrests the paroxysms of pain, which may lead to a mistaken diagnosis of odontogenic pain.

b- ***Continuous neuropathic toothache*** some neuropathic toothaches produce a persistent, ongoing unremitting pain. These pains may be exacerbated by local provocation, such as percussion of the tooth or touching the surrounding gingiva, which adds confusion to the diagnosis. The neuropathic conditions that can produce continuous toothache are neurotic pains (neuritis).Neurotic pain that arise in the maxillary and mandibular divisions of the trigeminal nerve can cause dental pains. Neurotic pains results from a spread of inflammation from surrounded structure to neural structures. The pain is often (continuous, aching, and burning in

nature). Occasionally neuropathic pain may arise after dental treatment, such as simple restoration, pulp extirpation, apicoectomy or extraction. These conditions may appear as a phantom tooth ache described by atypical odontalgia. Atypical odontalgia has been referred to as toothache with no obvious organic cause and is characterized by prolonged periods of throbbing or burning pain in the teeth or alveolar process that occurs in the absence of any identifiable odontogenic cause. Most commonly, this condition affects middle-aged Caucasian women, and the maxillary canine and premolars are involved.

Herpes Zoster (Shingles). A recurrence of herpes zoster infection involving the second and third divisions of the trigeminal nerve can be manifested in a rare prodrome of symptomatic pulpitis. Like any trigeminal nerve involvement, pulp pain is unilaterally confined. Toothache pain can be localized in one or more teeth, and is described as sharp, throbbing, and intermittent. The symptoms are believed to be genuine pulpal pain and not mimicked. A recent report suggests that varicella virus can lead to adverse pulpal responses; even necrosis. Other complications may include tooth exfoliation, internal resorption, and osteonecrosis.

Toothache of maxillary sinus origin. The apices of the maxillary canine to molar teeth may be separated from the sinus by a thin osseous plate or by a thin membrane. Inflammation of the sinus lining mucosa can evoke facial pain that involves all of the related maxillary teeth. Generally, teeth adjacent to the sinus have healthy pulps. They are sensitive to percussion, pain can increase with eating, involve the entire quadrant, or refer to the mandibular teeth on the same side. Patient reports fullness in the face, pain that increases with lying down or bending over, and tenderness of the skin overlying the sinus. In the differential diagnosis of maxillary sinusitis, the endoantral syndrome and barodontalgia, barosinusitis, or both, must be considered to rule out a coexisting endodontically induced infection of the sinus lining.

Toothache of myofacial origin. The muscles of mastication, particularly masseter, temporalis, and anterior digastric, can induce referred pain felt as tooth ache. It is common for a patient to complain of muscular pain after extensive dental treatment, during which the mouth has been open for extended periods. Pain usually increases with emotional stress or vigorous, extended use of the involved muscles.

Toothache of cardiac origin. The presence of jaw pain related to angina pectoris and myocardial infarction highlights the importance of recording each patient's medical history. Reports on the condition of cardiac induced jaw pain show approximately 10% of cases refer pain to the mandible. Myocardial pain may manifest itself in the form of pain in the left arm, especially down the inner aspect, as well as pain in the neck, jaw, or teeth. The attendant signs of shock, nausea, difficulty breathing, sweats, clammy skin, and pallor may accompany these symptoms. Radiographs and pulp tests of all the teeth in the painful area will appear normal. Sensitivity testing cannot reproduce the pain. Failure of analgesic blocking to arrest the pain completely confirms that the primary source of pain is not the tooth.

Atypical Odontalgia (Idiopathic or Phantom tooth)

First reported by McElin and Horton in 1947. The pathophysiology of atypical odontalgia remains unclear until the first hypothesis by Marbach 1978 who reported that atypical odontalgia was of similar etiology to phantom limb pain. He explained that after injury there is a change in the organization and activity of central and peripheral nerves, which may result in chronic pain and other related symptoms like paresthesia.

Chen & Cohen (2002), proposed that the etiology may be due to:

Sensitization of pain fibers, by sprouting adjacent afferent nerve fibers, or by sympathetic

activation of afferents and the loss of inhibitory mechanisms.

Epidemiologic information indicates that 3% to 6% of patients develop atypical odontalgia after endodontic treatment. It occurs among women in their mid-40s. Molars and premolars in the maxilla are most often affected

Clinical characterization:

1. Persistent toothache following pulp extirpations, apicoectomy, or tooth extraction, facial trauma after inferior alveolar nerve block.
2. Prolonged periods of constant throbbing or burning pain in teeth or the alveolar process. No odontogenic etiology observed clinically or radiographically.
3. The patient's sleep is undisturbed, and there may be a brief symptom-free period on waking.
4. Difficulty in localizing the pain.
5. Worst at the site of the original trauma, but can spread to adjacent areas, unilaterally or bilaterally.
6. Local anesthetic block gives unclear results, and patients rarely find relief with analgesics, including narcotics

Neoplastic Toothache

Orofacial pain may be the initial symptom of oral cancer and can motivate patients to seek care from their dental practitioners.

a. Squamous cell carcinoma (SCC)

- Primary squamous cell carcinoma (SCC) of the oral mucosa may present with pain and sensory disturbances that mimic toothache symptoms particularly when located on the gingiva, vestibule or floor of mouth.
- It was found that pain to be the first clinical sign of oral cancer in 19.2% of cases. These malignancies are extremely rare.
- Primary intraosseous SCC occurs within the jaws, has no initial connection with the oral mucosa, they can be mistaken for odontogenic origin since the clinical presentation of localized bone loss may have the appearance of localized periodontal disease.

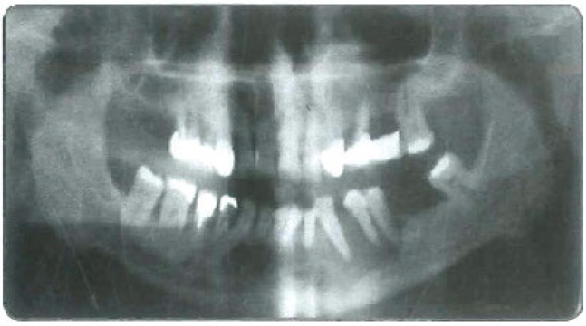


Fig. 6. Primary intraosseous SCC.

b- Nasopharyngeal cancers

May present with signs and symptoms that have been confused with, and treated as, tempromandibular disorders, parotid gland lesions, and odontogenic infections with trismus.

Signs and symptoms of nasopharyngeal carcinomas may mimic tempromandibular disorders, such as:

1. Facial pain.
2. Limited jaw opening.
3. Deviation of the jaw on opening.
4. Earache.
5. Headache.

c- Systemic cancers

Such as lymphoma and leukemia may have intraoral manifestations that mimic toothache symptoms.

Infiltrating pain with sensitive structures such as periosteum and gingiva, localized pain that may be confused with odontogenic and/or periodontal conditions.

In rare circumstances, the osteolytic lesions of multiple myeloma may develop adjacent to teeth. When this occurs, odontogenic pain is common and presents a radiologic diagnostic challenge as the osteolytic lesions appear to be associated with teeth but are actually related to the systemic disease.

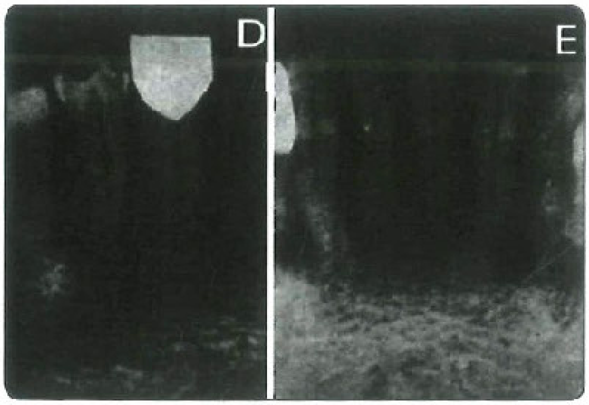


Fig. 7. Osteolytic Lesions in the mandible.

d- Distant non-metastasized lung cancers

The facial pain is almost always unilateral affecting the ear, jaws and temporal region, frequently described as severe and aching, and usually continuous and progressive. This may be confused with referred pain of odontogenic origin.

The referred facial pain of malignant origin can occasionally precede the appearance of neoplasm on routine chest films The tumor invasion and compression of the vagus nerve by the tumor was the presumed cause of pain.

e- Metastatic malignancies

Metastasis often develop from the breast in women and the lung and prostate in males, with the most common sites of occurrence in the jaws being the posterior mandible, angle of the jaw, and ramus.

In metastatic disease of the jaw bones pain has been reported in 39% and paresthesia in 23% of patients. The metastatic lesion in the oral region to be the first indication of an undiscovered primary malignancy at a distant site .

f. Chemotherapy

Chemotherapy-induced toxicity injuries to the peripheral nerve might manifest as pulpitis-like toothache.

Toothache of psychogenic origin. On occasion, a patient may report symptoms of toothache that do not fit any clinical orofacial pain entity. When the pain complaint is confined to a tooth, the condition may be described as a psychogenic toothache. A dentist should suspect a psychogenic tooth ache only after eliminating other organic causes of toothache. Munchausen's syndrome is characterized by an elaborate description or creation of pain that is not real or is self-inflicted. The psychotic or neurotic patient gives a history.

Periapical pain:

1- **Acute apical periodontitis (AAP):** tooth is painful to touch and occlusion. Pain is severe 24 hours a day and lasts for few days. Tooth is elevated in the socket. The pain is due to violent inflammatory reaction in the periapical area (osteitis).

2- **Acute apical abscess (AAA):** pain is similar to AAP but with lower intensity. Pain is developed by initial discomfort and may be mild, gradually build up in intensity, as abscess is indurated and hard. When alveolar plate of bone is eroded the pain decreases. Pain is evoked by heat due to expansion of gases, percussion greatly increases the periapical pressure due to wedging action of the tapered roots. Adjacent tooth may be tender due to collateral edema and is painful to percussion. Periodontal abscess differs than AAA in that; involved tooth is vital, mild response in percussion and normal adjacent tooth.

3- **Chronic apical periodontitis (CAA):** seldom painful.

4- **Apical cyst:** painless unless infected.

5- **Chronic apical abscess (CAA)**: it is called suppurative apical periodontitis.

It is symptom free in case of dry fistula. Some discomfort is shown on closing the sinus or fistula due to increase in periapical pressure. External root resroption is a common finding. It may develop phoenix abscess with typical signs and symptoms of acute apical abscess.

Chapter review Questions

1. A diabetic cardiac patient complaining from pain related to the upper and lower left molar area, diagnose and develop possible treatment modalities.
2. Analyze different ways of management for odontogenic infections.
3. Discuss different ways of management for odontogenic and nonodontogenic lesions.

References

- Hargreaves KM, Cohen S. Cohen's Pathways of the Pulp.10th ed. Mosby El Sevier, 2011.
- Ingle JL, Bakland LK, Baumgartner JC.Ingle's Endodontics 6. 6th ed. BC Decker Inc., 2008.
- Dahl E, Mjör IA. The structure and distribution of nerves in the pulp-dentin organ. Acta Odontol Scand. 1973 Dec;31(6):349-56.
- Moayedi M, Davis KD. Theories of pain: from specificity to gate control. J Neurophysiol 2013; 109:5-12
- • https://en.wikipedia.org/wiki/History_of_pain_theory

6

Management of Pain and Pain Saving Methods

Khaled M. Ezzat

Intended Learning objectives

After reading this chapter, the student should be able to

1. Understand the key of acute pain management.
2. Interpret , diagnose and treat the cause of pain.
3. Recognize the use of flexible analgesic prescription strategy.
4. Discuss the recent approaches to pain saving methods.

Postgraduate students should be able to

1. Criticize the key of acute pain management.
2. Rate the recent approaches to pain saving methods

Chapter Outline

Management of acute pain

Diagnose and treat the cause of the pain.

Use a flexible analgesic prescription strategy.

Pre-treat with non steroidal anti-inflammatory drugs.

Use long acting local anesthetics.

Recent approaches to pain saving methods

Management of acute pain

Acute inflammation often produces a condition known as hyperplasia, which is characterized by spontaneous pain, an exaggerated response to stimulation, and reduced pain threshold. Sunburn is a classic example of hyperplasia. The acute inflammation associated with pulpal and periapical disease will sometimes lead to hyperplasia. The management of pain due to inflammation is directed at blocking the development of hyperplasia. Key actions which help you achieve effective management of acute pain:

1 Diagnosing and treating the cause of pain.
2- Use a flexible analgesic prescription strategy.
3- Pre-treat with nonsteroidal anti-inflammatory drugs (NSAIDs).
4- Achieve profound anesthesia; and use long acting local anesthetics when indicated.

1) Diagnose and treat the cause of the pain.

Acute pain is generally a symptom of underlying problem. Managing the symptom, the pain alone, generally does not cure the problem. In most cases of acute dental pain, drug therapy is only adjunct to dental treatment. Often, dental treatment alone can result in substantial pain relief such as the immediate reduction of pain that can follow incision and drainage of an abscess or the relief that can be accomplished by pulpectomy of an irreversibly inflamed pulp.

Consequently, before drug therapy can be considered, the first steps in pain management are:

- Make an accurate diagnosis.
- Provide effective treatment

If an accurate diagnosis cannot be reached, the patient should either be re-appointed for subsequent reevaluation or referred to a specialist. Because of their years of training and experience with diagnosing dental pain, endodontics can be a resource for the difficult to diagnose pain problem. The subjective questioning should attempt to provide a narrative from the patient that addresses the patient's own words, included the following:

1- Location of the chief complaint. The patient is asked to point the source of pain directly. The dentist can note if the pain is intraoral or extraoral, precise or vague, and localized or diffused. If symptoms radiate, or if the pain is referred, the direction and extension can be also demonstrated.

2- Onset of symptoms. The patient should relate when the symptoms of the chief complaint were initially perceived. The vast majority of patients with toothache have a previous history of pain in the same location.

3- Characteristics of pain. The pain can be classified as severe if it interrupts or significantly alters the patient's daily routine. Pain usually indicates tissue damage and to some extent, reflects the extent of damage. However, sometimes fear of dentists and dental procedures causes an exaggeration of perceived pain, resulting in an inconsistency between symptoms and pulpal pathosis. It is important for the dentist to record details of symptoms.

a- *Quality of pain.* The patient is asked to give a description of each symptom associated with the odontogenic pain. This description is important for the differential diagnosis of pain and for selection of objective clinical tests to reproduce symptoms.

- Dull, gnawing and aching describe pain of bony origin.
- Throbbing, pounding, pulsating describe the vascular response to tissue inflammation.
- Sharp, electric, recurrent, or stabbing pain usually caused by pathosis of nerve root complex, sensory ganglia, or peripheral innervation, which is associated with irreversible pulpitis or tri-geminal neuralgia.
- A single episode of sharp, persistent pain can result from acute injury to a muscle or ligament as tempromandibular joint dislocation or iatrogenic perforation into the periodontal attachment apparatus.
- Pulpal and periapical pathosis produce sensations that are described as aching, pulsating, throbbing, dull, radiating, stabbing, or jolting pain. The diagnostician should not ignore the fact

that many of these adjectives can also describe nonodontogenic pathosis.

b- *Intensity of pain*. The patient's perception of and reaction to pain is widely variable. The dentist, therefore, should try to quantify the intensity level of the pain symptoms reported by the patient. Patient should try to quantify the pain, from no pain to severe or intolerable. Patient should classify the pain as mild, moderate, or severe.

- The Numeric Rating Scale (NRS-11) is an 11–point scale forpatient self-reporting of pain.
- It is for adults and children 10 years old or older.
- NRS-11

Table (1) Numeric Rating Scale

Pain Level	Rating
No Pain	0
Mild Pain (nagging, annoying, interfering little with ADLs [activities of daily Living])	1-3
Moderate Pain (interferes significantly with ADLs	4-6
Severe Pain (disabling; unable to perform ADLs)	7-10

Heft-Parker visual analogue scale (VAS Scale)

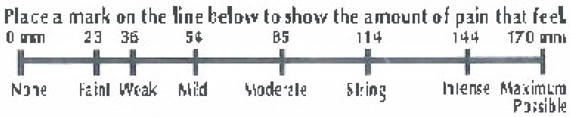


Fig. 1: Heft-Parker visual analogue scale (VAS)

4- Factors affecting pain symptoms The objective of this part of examination is to identify which factors provoke, intensify, alleviate, or otherwise affect the patient's symptoms. The stimuli generally associated with odontogenic symptoms are heat, cold, sweet, percussion, biting, manipulation, and palpation. A history of prolonged, painful responses to thermal changes suggests a problem of pulpal origin. Clinical tests using the thermal test that most closely reproduces the patient's complaint are indicated to locate the source and intensity of the response. The dentist must inform the patient that it may be necessary to wait a while for vague symptoms to localize. This conservative approach is sometimes necessary when pathosis is confined to the pulp, which can refer pain to other teeth or nondental sites.

5- Supplementary history-the pain diary. A daily diary can provide valuable information to aid in the difficult diagnosis. A pain diary provides an hour by hour or day by day narrative that can help the clinician determine if the pain is odontogenic or nonodontogenic.

After organizing, analyzing, and assimilating all of the relevant descriptions, facts, and data, the dentist should be ready to proceed with clinical-examination phase of the diagnostic process.

2) Use a flexible analgesic prescription strategy.

It is important to note that analgesics do not have any therapeutic effect on the underlying disease and they essentially only act by blocking the pain sensation being experienced by the patient.

The majority of painful dental problems that require analgesics is due to inflammation of one of the oral, dental or associated tissues, this inflammation may be a result of various factors such as infection, trauma and following an operative procedure.

- If the pain is caused by infection antibiotic prescription will be required.
- If the problem is purely inflammatory in origin an anti-inflammatory drug would be indicated.

Analgesics

i. Non-narcotics

Used for mild and moderate pain by inhibiting the prostaglandin synthesis.

a) *Non steroidal anti-inflammatory drugs (NSAIDS):*

Aspirin

Ibuprofen (Advil) diflunisal (Dolobid) piroxicam (Feldene)

b) *Antipyretic analgesics*

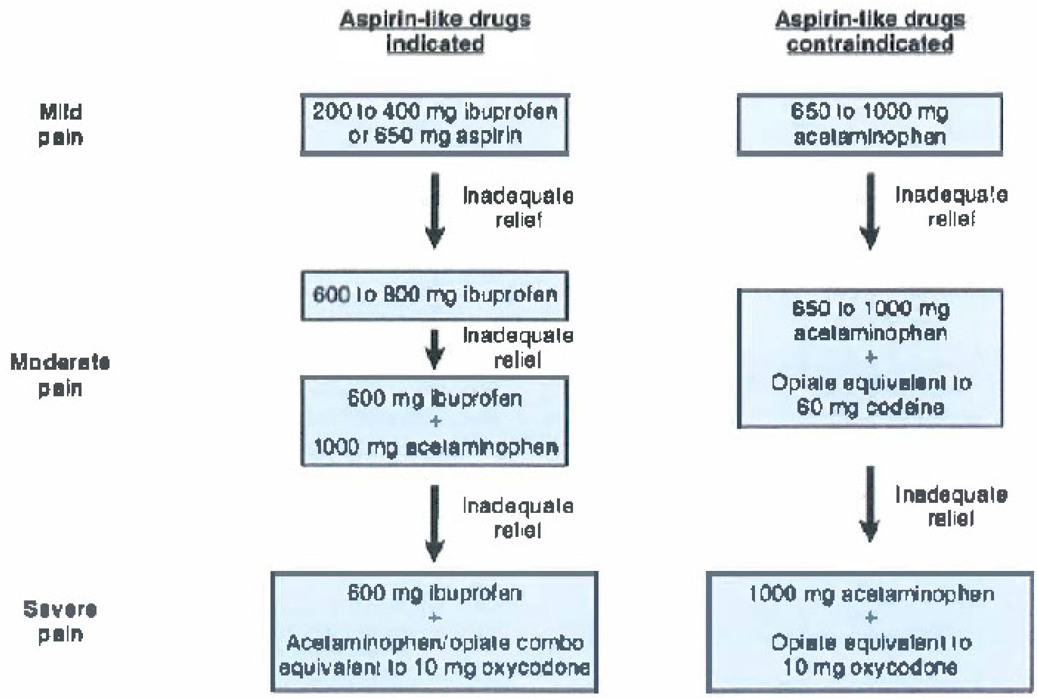
Acetaminophene (Tylenol)

ii. Narcotics

Used for moderate to severe pain, its action affects primarily the CNS, its disadvantages is it requires high tolerance, high patient dependence and devoid of anti-inflammatory activity.

- Morphine.
- Methadone.
- Mepridine (Demerol).
- Codeine

Table (2) Flexible analgesic plan



Flexible analgesic plan

Each patient in your practice is unique. Each has different needs. If you always prescribe the same analgesic, some patients will be under-medicated and experience unnecessary pain while some will be over-medicated and experience unnecessary side effects. So a flexible prescription plan is recommended. The strategy for this plan is to begin by prescribing a maximally effective dose of a non-narcotic analgesic and then later prescribe a narcotic analgesic only if the pain continues.

3) Pre-treating with NSAIDs.

The use of pretreatment and post treatment analgesics may significantly reduce the incidence of flare-ups, especially for patients in moderate to severe pain. Because endodontic pain results from numerous inflammatory and immunologic pathways, most endodontists prefer NSAIDs to narcotics for interfering with this process and reducing pain symptoms. NSAIDs inhibit the production and release of chemical mediators of inflammation. In addition, aspirin is generally not used to pre-treat patients, especially before surgical procedures, where aspirin can increase bleeding.

4) Using long - acting local anesthetics

It is important to achieve profound anesthesia prior to initiating treatment. It is equally important to ensure that the anesthesia is of adequate duration. Adequate anesthesia not only ensures comfortable treatment but also reduces post-operative pain. Combining NSAIDs pretreatment

with the use of long acting local anesthesia can result in nearly 70% of patients reporting pain as either none or slight, even at 7 hours after surgical removal of impacted molar.

To achieve a Painless injection the operator should do:

a. Topical anesthetic.
b. Stretching the mucosa.
c. Slow injection.
d. Warming the anesthetic solution.
e. Two stage injection.
f. Gentle insertion of the needle.

Mechanism of action of L.A:

a. LA mainly blocks the voltage gated sodium channels preventing nerve depolarization.
b. LA blocks classes of G-protein coupled receptors that respond to endogenous algogenic substances (inflammatory mediators) that induce analgesia.

Types of anesthetic drugs

There are many types of local anesthetic drugs. Lignocaine is the gold standard among other types, as it proves high efficacy, low allergenicity and low toxicity. Recently Articaine was introduced to the market.

Articaine:

a. Faster onset of action.
b. Longer duration of action.
c. Higher success rate.
d. Greater potency (1.5 times more potent).
e. Lower systemic intoxication.
f. Used safely in pregnancy.
g. The neurotoxic effects of articaine is higher in the form of paresthesia.

Oraverse

Patients get annoyed from lip numbness after the dental visit. So injection of oraverse will relief this sensation. This drug composed of phentolamine mesylate. It is a non-selective alpha adrenergeic blocker causes vasodilatation that leads to a rapid washing away of the local anesthetic agent.

The selection of a local anesthesia for use in dental procedure should be based on the following criteria:

a. Duration of the dental procedure.
b. Requirement for homeostasis.
c. Requirement for post-surgical pain control.
d. Contraindications to the selected anesthetic drug or vasoconstrictor.

So, pain management protocol could be summarized as follow:

Control anxiety, deal with fear first, then pain will be a minor problem, as anxiety leads to true fear that lowers the pain threshold. Highly nervous patients metabolize anesthetics rapidly.

Anxiety reduction could be achieved by:

a. Iatrosedation, confidence, control, concern and communication.
b. Pharmaco-sedation by oral sedatives are taken the night before and one hour prior to surgery to facilitate treatment

Inhalation sedation. Nitrous oxide is used with apprehensive patients or who have a low pain threshold.

1- Preoperative oral NSAIDs, 1 hour before start of treatment
2- Local anesthetic of choice for pain control during surgery.
3- Local anesthetic administration at END of procedure immediately prior to dismissal of patient.
4- Continue oral NSAIDs on timed basis.

Stress Reduction Protocol (for medically compromised patients):

a. Professional confidence, by the operator when dealing with the patient.
b. Avoid or minimize pain as possible, patient assurance to do so.
c. Preoperative sedation by medication.
d. Intra-operative sedation, topical and local anesthesia.

e. Schedule morning appointments.

f. Avoid surprises, explain to the patient what he is going to experience during and after operation.

g. Ensure postoperative pain control.

Recent approaches to pain saving methods

The extreme variability of toothache is such that a good rule for any examiner is to consider all pains about the mouth and face to be of dental in origin until provide otherwise. The ability to provide excellent, high-quality pain control in endodontic practice is based on a practical knowledge of the causative factors; endodontic pain is best managed by eliminating these causes. Many attempts were made to control pain before, during, and after dental intervention. Here we are presenting some of the recent approaches to control pain.

1- **Targeted Electronic Anesthesia (TEA) system.** The TEA system presents the 21st century alternative to the traditional syringe. The TEA system is an invasive form of anesthesia that blocks pain electronically, using the same cellular mechanism as local chemical anesthesia. It provides pain control for restorative dental procedures without the use of needles or postoperative discomfort, numbness, and swelling.

2- **The Computer-Assisted System.** The computer-assisted system outperforms syringes for traditional injections. The new system generates a precisely controlled anesthetic flow rate that eliminates the need for the operator to use thumb pressure to administer anesthesia.

   A- The Wand device: It has aspiration feature to avoid intravascular administration. Provides a computer controlled rate for L.A administration, using a built-in microprocessor. The rates of injection is:

   - Slow for palatal injections.
   - Fast for buccal infiltrations.
   - Turbo for block anesthesia.

   B- Single tooth anesthesia system: Introduced in 2007 (Milestone Scientific). It has a "Dynamic Pressure Sensing DPS module" which provide feedback to the operator about the tissue pressure at the needle tip to determine the ideal needle position for "intra-ligamental injections" and is being tested for producing predict able "intra-pulpal" anesthesia.

3- **The use of pulsed Nd.YAG laser and Co2 laser.** Nd: YAG laser is advocated as an alternative mean of providing analgesia during routine dental procedure. The mean responses measured 5 min after laser treatment with 113-mJ p at 15 pulses (pps) for 3 minutes. The pain threshold returned to baseline value after 60 min. Nd: YAG laser treatment is also used to decrease dentin hypersensitivity without detrimental pulpal effects. Other, studies used Co2 laser in the treatment for the reduction and elimination of dentinal hypersensitivity.

4- **Transcutaneous Electric Nerve Stimulation (TENS).**

   - It is based on TENS concept and gate control theory for blocking pain
   - Idea: keeping the nerves busy with some electrical signals via vibrations, just like the telephone with a busy signal
   - It is used as a supplement for the traditional LA

   Advantages:

   a. No need for needle

   b. Remains for several hrs

   Disadvantages:

   a. No extended analgesic effect after its removal.

   b. No vasoconstriction action.

The TENS is used in many fields of medicine to provide safe and effective pain relief, yet application of this technique in dentistry remains almost unexplored. The pain is eliminated or minimized under TENS at 99 Hz. Patients preferred high-frequency TENS because of the accompanying sensations of warmth and relaxation.

TENS seems not to be useful in the case of painful dental interventions.

5- **The Audio Analgesia.** Audio analgesia (music and random noise)and electronic dental anesthesia may be used with considerable-success in pain suppression and control.

6- **Electro-acupuncture (EAP).** EAP proved to produce analgesia.

7- **The virtual reality.** The virtual reality is a uniquely attention-grabbing medium capable of maximizing the amount of attention drawn away from the "real world", allowing patients to tolerate painful dental procedures. Virtual reality may also have analgesic potential for other painful procedures or pain populations.

Nonstop attempts are made to introduce new methods, techniques, and medications to overcome the man's second enemy, the PAIN. The use of these modified techniques may have a positive influence on patient safety, patient comfort, and office productivity.

8- **Intra-oral lignocaine patch [DentiPatch]:** Contains 10-20% lidocaine, placed on the dried mucosa for 15 minutes. It is recommended for use in achieving topical anesthesia for both maxilla and mandible

9- **INJEX needleless device :**

Indications :

a. Infiltration of L.A.

b. Paediatric dental work

c. Anterior deciduous teeth

Contraindications:

a. Nerve block

b. Using for adult patients (Fig. 2)

Advantages: Needleless

Disadvantages:

a. Not effective in all techniques

b. Need specific device

c. Patient feels pressure during solution administration

10- Nanotechnology in anesthesia

Colloidal suspension containing analgesic in nanobots

Controlled through nanocomputer to reach D.T. then pulp and release drug. After finishing work, the dentist order nanobots to restore all sensations.

Advantages:

a. Patient comfort and reduced anxiety

b. No needles

c. Fast and completely reversible

d. Avoidance of most side effects and complications

11- Buffering the anesthetic solution:

In February 2011 in the United States, a system was introduced that enables consistent and accurate buffering of local anesthetic solutions. The addition of sodium bicarbonate with the aid of the device, the pH-value of the local anesthetic solution is increased.

The higher PH leads to:

a. Less burning sensation during injection.

b. Less post-treatment soreness is achieved.

c. More rapid onset of action through the nerve membrane to block sodium channels.

d. Less tissue damage

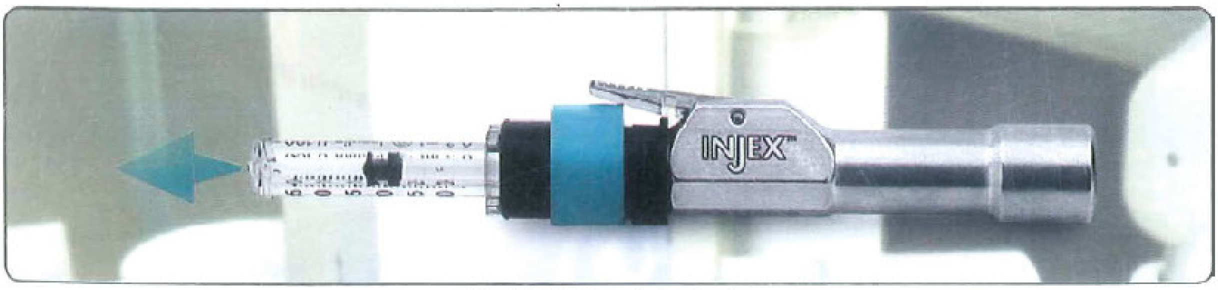


Fig. 2. INJEX needleless device

Chapter review Questions

1. Assess different drugs used for control of odontogenic pain according to patient illness and body condition.
2. Discuss 3D approach in management of acute periapical lesions (emergency).

References

- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Aggarwal V, Singla M, Kabi D. Comparative evaluation of anesthetic efficacy of Gow-Gates mandibular conduction anesthesia, Vazirani-Akinosi technique, buccal-pluslingual infiltrations, and conventional inferior alveolar nerve anesthesia in patients with irreversible pulpitis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 109:303,2010.
- Aggarwal V, Singla M, Miglani S, Ansari I, Kohli S.A prospective, randomized, single blind comparative evaluation of anesthetic efficacy of posterior alveolar nerve blocks, buccal infiltrations, and buccal plus palatal infiltrations in patients with irreversible pulpitis. J Endod 37:1491, 2011.
- Ramachandran A, Khan SI, Mohanavelu D, Kumar KS. The efficacy of pre-operative oral medication of paracetamol, ibuprofen, and aceclofenac on the success of maxillary infiltration anesthesia in patients with irreversible pulpitis: a double-blind, randomized controlled clinical trial. J Conserv Dent 15:310, 2012.
- Parirokh M, Sadr S, Nakhaee N, Abbott PV, Askarifard S. Efficacy of supplemental buccal infiltrations and intraligamentary injections to inferior alveolar nerve blocks in mandibular first molars with asymptomatic irreversible pulpitis: a randomized controlled trial. Int Endod J 47:926, 2014

7

Pulpal and Periapical Diseases

Karim Galal Abd El Kader

Intended Learning objectives

After reading this chapter, the student should be able to

1. Understand the aetiology of pulp and periapical diseases.
2. Understand the physiology and pathology of pulp and periapical diseases.
3. Classification of pulpal diseases and their clinical/histological features.
4. Classification of periapical pathosis and their clinical/histological features.
5. Identification of characteristic (pathognomonic) features that differentiate between acute and chronic pulpal and periapical lesions
6. Correlation between histopathology and clinical outcome of pulpoperiapical diseases.

Postgraduate students should be able to

1. Discuss etiologic factors causing pulpal inflammation
2. Identify the factors determine pulp tissue response to an irritant
3. Identify various classifications advocated for pulp disease.
4. Distinguish clinical and radiographic features of pulpal diseases
5. Identify etiologic factors causing periapical inflammation/lesions
6. Classify periapiac lesions of pulpal origins
7. Distinguish clinical and radiographic features of periapical lesions of pulpal origin

Chapter Outline

The **inflammatory process** in the **pulp** is basically the same, as elsewhere in the body connective tissue. In the pulp, there are **several factors**, that change the response (irreversible process, pulp cannot regenerate) due to:

1) The **pulp** is a **unique** C.T., that is almost **totally surrounded by hard tissue,** limiting the area for tissue expansion. Thus restricting the pulp's ability to tolerate oedema causing irreparable damage, due to stagnation or strangulation of the pulp circulation.
2) **Lack of collateral circulation** (main circulation is through the apical foramen and accessory canals).
3) Pulp is the only organ that can **produce reparative dentine.**

Pathways of the pulp:

It is the route taken by microorganisms to reach the pulp.

1) **Direct extension**: Through the dentinal tu bules, as in case of: **caries chemicals** placed on dentin.
2) **Anachoretic:** Localisation of blood born bacteria within the pulp, as blood coming from remote areas, as maxillary sinus.
3) **Extension of periodontal disease** through:
   lateral canals.
   apical foramen.

Etiology of Pulp Inflammation

1) Microbial:

- **Bacteria** and their products are the most common cause for endodontic diseases.
- **Bacteria** enters the pulp through any of the previous pathways. The response depends on:

$$\frac{\textbf{No. of micro-organisms x Virulence}}{\textbf{Tissue resistance}}$$

2) Iatrogenic:

I) *Physical:*

1) **Pressure:**

Increase pressure will lead to increase friction which will lead to increase heat production which will increase possibility of pulpal irritation

2) **Speed (RPM):**

Increase RPM which will lead to increase friction which will increase heat.

a) **Conventional speed**: Such low speed requires the application of more pressure increasing heat production (most dangerous speed, ranges from **3000 –30000 RPM**).

b) **Air motor** (**ultra high speed,** ranges from **50000 – 500000** RPM) is the most efficient speed range, because it does not require pressure application.

Size of the instrument:

Larger size produce more friction causing more heat generation.

3) **Depth of cutting:**

The most critical factor in determining the degree of pulp response. **Remaining dentine thickness** is measured from the floor of the cavity to the pulp tissue. As **dentin** is the **best insulator**, thus more dentine thickness give better insulation.

- The **safest** dentin thickness, **is 2 mm**, especially when using conventional speed.

4) **Presence or absence of an insulating base:**

- It is important postoperatively together with the remaining dentin thickness to isolate heat.
- We could use a **base** only or a **base and sub-base**, especially when filling a deep cavity with amalgam.

5) **Other physical factors**:

a) **Loss of enamel** due to abrasion or erosion leads to exposure of dentinal tubules.
b) **High filling** causing frequent pulpal trauma.
c) **Hot impression** material or wax.
d) **Tooth drifting**.
e) **Orthodontic treatment**, if forces beyond tooth's physiological limit are applied.

II) ***Thermal:***
1) **Pressure:** (as in physical).
2) **Speed:** RPM (as in physical).
3) **Depth of cutting:** (as in physical)

Type of cutting instrument:
Abrading instruments are much more **dangerous** than **drilling** instruments, due to their broader surface area.

4) **Coolants:**
- An efficient coolant must be used.
- The most efficient coolant system is **air-water spray**, as air alone is not enough and it must be accompanied by water, either as: **spray** or **water jet**
- If an **efficient coolant** is to be used with high speed, the remaining dentin thickness is to be brought to **0.3 mm** of the pulp.

Metallic filling without proper insulation:
Transmits environmental thermal changes to the pulp, already irritated by cavity preparation.
Heat generated by setting cement and polishing of restorations.

III) ***Chemicals:***
A) **Chemicals used for cleaning of the cavity:**

Phenol:
Must be applied for a long duration, to be effective causes pulp irritation.

Ether and chloroform:
When they **evaporate** produce
a) Heat generation
b) Withdrawal of some fluid from dentinal tubules which will lead to desiccation and irritation.

Hydrogen peroxide:
Gives rise to **nascent oxygen**, which may enter through open dentinal tubules to the pulp causing embolism and strangulation of the blood vessels leads to degeneration of supplied areas.

Silver nitrate:
Causes **coagulation** of pulp proteins and some sort of inflammation followed by necrosis.

B) **Chemicals used during filling of the cavity:**
Orthophosphoric acid of zinc phosphate cement is an irritable material.
Acids of acrylic resin and composite are also severely irritant.

3) **Traumatic:**
a) The **response** to trauma appears dependant on the **severity** of the trauma.
b) The response to trauma from an accident or biting on a hard object may vary, where:
1) Some pulps **heal** with no adverse effect.
2) Some teeth respond to trauma by inducing pulpal **calcification**.
3) Some teeth become **necrotic**, as trauma causes inflammation and cut of blood supply.

4) **Idiopathic:**
Internal resorption. (as seen later)

Classification of Pulp Inflammation

1) **According to severity and duration:**
i) **Acute:** Characterised by formation of exudates.
ii) **Chronic:** Characterised by proliferation of tissues forming granulation tissue (young fibroblasts, young blood vessels and young nerve fibres).
iii) **Subacute.**

2) **According to presence or absence of symptoms:**
i) **Symptomatic.**
ii) **Asymptomatic.**

3) **According to the ability to heal:**
i) **Reversible.**
ii) **Irreversible.**

Pulpal Diseases

I) Inflammatory diseases of the pulp:

Hyperaemia
Acute pulpitis
Subacute
Chronic pulpitis

II) Additional pulp diseases:

Necrosis
Retrogressive pulp changes:
Atrophy
Calcification
Internal resorption

1) Hyperaemia (reversible pulpitis):

(The only reversible condition of the pulp)

- **Definition:**

A local vasodilatation that leads to elevated capillary pressure, increased vascular permeability, with predisposition of oedema.

- **Pathogenesis:**

1) Vasodilatation.
2) Increase amount of blood in the vessels.
3) Increase pressure leading to increase vascular permeability and fluid exudate.

N.B.: The pressure produced is a subliminal pressure: less than the pain threshold of the pulp organ.

- **Examination and Diagnosis:**

I) **Visual examination:**
   A) Carious cavity.
   B) Recently filled deep cavity without a protective base.
   C) Recent trauma.

II) **Signs and symptoms:**
   - Shock pain, which is **sharp** and of **brief duration**, it is triggered by mild irritation (heat, cold, sweat or sour)
   - Pain stops immediately, as the irritant is removed.
   - No spontaneous pain.

III) **Percussion:** -ve

IV) **Radiographically:** normal

V) **Vitality tests:**
   a) **Thermal test is** +ve, especially cold application.
   b) **Electric pulp tester** (Vitalometer) has a +ve response at low current.

- **Treatment:**
- **Treating the cause**, e.g.:
   a) Filling a carious cavity.
   b) Removal of a deep filling and place a temporary filling for 1 week or 10 days, before making a new filling with an underlying base.
- The **best treatment is prevention**, e.g.:
   a) Control of operative procedures.
   b) Sedative base should always be used in deep cavities.

2) Acute pulpitis (irreversible pulpitis) Hot Tooth:

- **Definition:**

A **clinically detectable** severe, painful and **irreversible acute inflammatory** response of the pulpal C.T to an irritant, in which exudates are hyperactive and play a dominant role.

- **Pathogenesis:**

1) Vasodilatation.
2) Increase vascular permeability and capillary pressure with loss of plasma proteins.
3) Fluid exudation and leucocytic infiltration that follows. More increase in intra-pulpal pressure, which will reach the pain threshold for the nerve ending, causing PAIN.
4) Blood flow is slow, congestion and stasis results.
5) Regional tissue cells are deprived of their O2 and nutrition leading to necrosis.
6) Intra-pulpal pressure and pain continue to increase, as pus forms and haemorrhage occurs from the rupture of blood vessels.
7) Continuing spread of local inflammation, which leads to a necrotic pulp as an end result.

- **Stages:**

I) **Early (Incipient) stage:**
   Hot; pain increase, due to increase vasodilatation and increase pressure on C-fibres (Hot Tooth)

Cold, pain increase due to hydrodynamic theory (movement of fluids in dentinal tubule, result in deformation of **A delta** fibres

II) **Advanced stage:**

Hot; pain increase, due to increase vasodilatation and increase pressure (HOT TOOTH)

Cold; pain is relieved, due to contraction of:

- Blood vessels
- Exudate fluid and the patient may come to the dental office with a piece of ice to relieve pain.

N.B: Cold dose not cause pain because A delta fibres die at late stage and presence of secondary irritants.

- Examination and Diagnosis:

I) **History and Visual examination:**

A) History of carious cavity.

B) Recent deep filling with no base.

C) Trauma.

D) Crown reduction without sufficient cooling.

II) **Signs and Symptoms:**

- **Severe or sharp excruciating throbbing pain, can be Spontaneous or :**

A. **Caused** by an **irritant**, but lingers for some time after the removal of the cause.

B. Pain **increase at night** or when the patient lies down, due to increase of cephalic blood pressure, increase intra-pulpal blood pressure.

C. **Diffuse or referred pain**, because pulp has only sensory nerve endings, while pain localization requires the presence of both sensory and proprioceptors.

III) **Percussion tests**: -ve

IV) **Radiographically**: normal

V) **Vitality tests:**

- **Thermal**:

- In the **early stage**; both hot and cold increase pain.
- In the **advanced stage**; heat increases pain while cold decreases it.
- **Electric** (Vitalometer); +ve response at a low current.

- **Treatment:**

Root canal therapy.

N.B.: Differential diagnosis between hyperemia and acute pulpitis.

1) **Reversible pulpitis** causes a **momentary painful response** to the **thermal change** that **subsides** as soon as the stimulus is recorded. **However irreversible pulpitis** causes **painful response** to **thermal change** that lingers after the stimulus is removed.

2) **Reversible pulpitis does not** involve a complaint of **spontaneous pain**, while irreversible pulpitis includes a complaint of spontaneous pain.

3) Subacute pulpitis:

A case in between acute and chronic. characterised by mild to moderate pain and treatment by root canal therapy.

4) Chronic pulpitis:

- **Definition:**

An inflammatory response of pulpal C.T. to an irritant in which **proliferative** forces are hyperactive and play a dominant role, i.e irritant is a stimulant for proliferation of granulation tissue.

Proliferation = Formation of granulation tissue. (tendency for healing)

A) **Chronic pulpitis** is asymptomatic, as there is an outlet for exudate through:

- Carious cavity
- Venous or lymphatic circulation.

So the pressure did not reach the pain threshold.

B) The **low grade irritation** stimulates formation of **granulation tissue**:

- Young fibroblasts
- Young blood vessels.
- Young nerve endings.

N.B.: Granulomatous tissue (fibrous tissue + chronic inflammatory cells)

C) If the tooth with **chronic pulpitis** is filled with **temporary filling**, the pathway for exudates is closed and **pressure increase** causing oedema and pain.

- **Classification:**

A) **Chronic ulcerative pulpitis:**

It is a **chronic inflammation** of a cariously exposed pulp, by the formation of an **abscess** at a point of leading to ulceration.

The pulp is formed of 3 zones:

1) **Zone of necrosis**: Inner most zone formed of necrotic tissue releasing exudate and necrotic by-products.
2) **Zone of contamination**: Middle zone, that consists of exudate + chronic inflammatory cells.
3) **Zone III**: Outermost zone, that consists of granulation tissue.

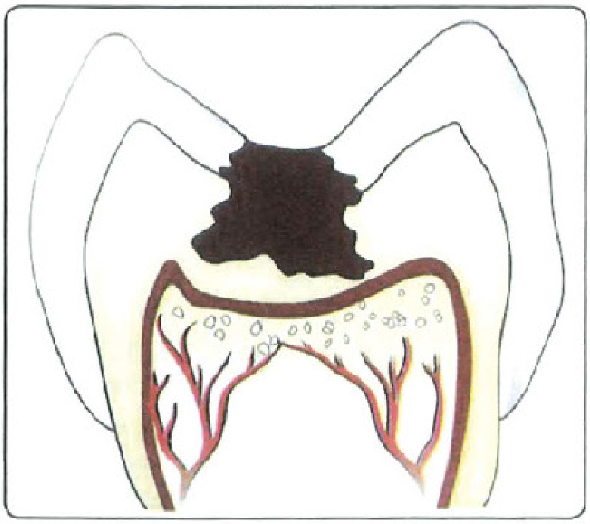


Fig. 1. Chronic Pulpitis

B) **Chronic hyperplastic pulpitis (pulp polyp):**

This **chronic inflammation** of cariously exposed pulp is characterised by overgrowth of **granulomatous tissue** into the carious cavity, forming a **polyp** which is usually lined by stratified squamous epithelium of mucosa.

- It occurs in young patients or adolescents, especially those having a proximal cavity.

- **Polyp is** - pinkish in colour
  - easily bleeding
  - not sensitive

- **Diagnosis and Examination:**

I) **Visual examination:**

History of a long standing carious cavity.

Visually: ulcerated lesion and large carious cavity in chronic ulcerative cases.

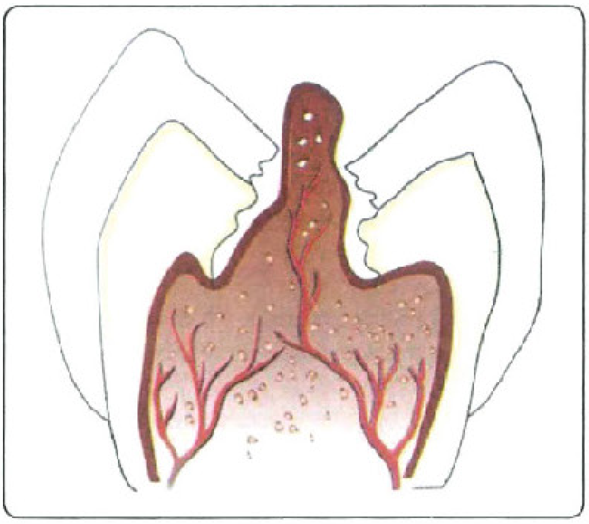


Fig. 2. Pulp Polyp

Pinkish polyp which bleeds easily in chronic hyperplastic.

II) **Signs and Symptoms:**

No or slight pain so called asymptomatic because product of exudative zones is drained away through:

1) Carious cavity.
2) Venous or lymphatic circulation.

III) **Percussion:** -ve

IV) **Radiographically:** normal

V) **Vitality tests:**

Themal test no response or may be delayed response with heat.

Electric pulp test responds at high current

- **Treatment:**

Root canal therapy for ulcerative pulpitis.

Cauterisation of the polyp, followed by root canal treatment for **hyperplastic pulpitis**.

Additional Pulp Diseases

1) **Necrosis:**

- **Definition:**

Death of pulp tissue **in sequel of:**

a) **Acute and chronic inflammation.**
b) **Immediate arrest of circulation due to traumatic injury.**
a) **It could either be** complete **or** partial e.g. **one root of a multi-rooted tooth or involving the pulp chamber while the root canal is still vital.**

- **Classification:**

I) **Liquifactive necrosis:**

Occurs when there is **good blood supply** i.e. acute or chronic inflammation.

Characterised by the presence of pus.

- Proteolytic enzymes cause proteolysis.
- Cells die and autolytic enzymes produce autolysis.
- Anaerobic bacteria release putrifiying enzymesn causing putrifaction then pus.

II) **Coagulative necrosis:**

Occurs, when there **is poor blood supply** e.g. trauma.

Characterised by a soft solid cheesy-like mass **(caseation)**, this mass is formed of coagulated protein, fat and little amount of water.

- **Diagnosis:**

I) **History and visual examination:**
History of carious tooth or trauma. The tooth is **dark** in colour (due to affection of dentin by necrotic tissue or extravasated R.B.Cs).

II) **Signs and symptoms:** painless

III) **Percussion:** -ve

IV) **Radiographically:** normal or slight widening of the lamina dura.

V) **Vitality tests: -ve**, except in cases of:

a) **Partial necrosis.** As **multirooted teeth** may give **+ve** response, if only one root is totally necrotic and other roots are not.

b) **Liquifactive necrosis,** where the fluid present will transmit a current to the periodontal ligament; **false response.**

- **Treatment:**

Root canal treatment must not be done in one visit, where in the first visit the clinician cleans and shapes the canal using crown down technique.

2) Retrogressive pulp changes

Irritation of the tooth induces aging of the pulp called: - catabolic - aging - dystrophic

I) *Atrophy:*(fibrosis)

- **Definition:**

Wasting away or decrease in the size of an organ due to faulty nutrition.

- **Histopathology and pathogenesis:**

a) Decreased no. of cells.

b) Decreased ground substance.

c) Increase mature collagen fibres **(like crabgrass)**; these bundles cause anoxia or hypoxia of the cells; the cells shrink and their nuclei become pyknotic.

- **Diagnosis:**

I) **History andvisual examination:**
History of caries, attrition,erosion or trauma.

II) **Signs andsymptoms: painless**

III) **Percussion:** -ve

IV) **Radiographically:** normal

V) **Vitality tests:** -ve or shows a slight response to a very high current.

- **Treatment:**

May be left untreated, unless the patient complains.

II) *Calcification (Chalky Tooth):*

- **Definition:**

Calcium deposits in the pulp chamber or root canal.

- **Classification:**

A) **Pulp stone (denticles):**
More common in the pulp chamber.

a) According to **location:**

- **Free** (lying free in the pulp chamber)
- **Attached** (due to further calcium deposition)
- **Embedded** (more dentin laid around them)

b) According to **structure:**

1) **True denticles:**
Not dystrophic in structure, composed of **dentin** formed by:
- Detached odontoblasts
- Proliferation of fragment of epithelial sheath of Hertwig.

2) **False denticles:**
In which deposition of calcium salts in dead or degenerated tissue occurs, due to the alkalinity of the destroyed tissue, which acts as **central nidus** for **deposition** of concentric layers of calcified tissues called **calcific-metamorphosis** or **dystrophic calcification.**

B) **Diffuse calcification:**
More common in the root canal alongside walls of blood vessels and nerves.

- **Diagnosis and examination:**

I) **History and visual examination:** Affected tooth may give history of trauma, or caries.

Visually: The tooth looks **lifeless**, takes the colour of a piece of chalk **(chalky tooth)** because enamel does not show normal translucent appearance being on fully calcified background.

II) **Signs and symptoms:** Painless
III) **Percussion:** -ve
IV) **Radiographically:**
Calcific changes could be seen
V) **Vitality tests:** Response at a very high current or no response, depending on the degree of calcification..
- **Treatment:**
No need for treatment unless patient is complaining.

III) ***Internal resorption (pink spot):***
- **Etiology:**
The exact etiology is unknown, but may be due to:
- Trauma - Inflammation - Idiopathic
- **Pathogenesis:**
Trauma causes:
1) Intra-pulpal haemorrhage.
2) Extravasation of blood, which changes into granulation tissue.
3) This tissue proliferates on the internal wall causing stimulation of dentinoclasts, resorption of interior wall, scalloping **(Hawship's lacunae)**.

This process can go on until:
1- A thin layer of dentine or enamel is left, so that red capillary granulation may be seen through enamel **(pink spot)**.
2- Actual perforation, where it may open into the periodontal ligament.

- **Diagnosis and examination:**

I) **History and visual examination:** History of chronic inflammation or trauma. Pink spot can be seen.
II) **Signs and symptoms:** No pain
III) **Percussion:** -ve
IV) **Radiographically:** Area of internal resorption could be seen on the radiograph.
V) **Vitality tests:** When dentin was removed from the resorbed area response at low current would follow.
- **Treatment:**
Root canal treatment, which should be done immediately.To wait and see mean loss of tooth structure.

Pulpo-periapical Pathosis

Definition:
Pulpoperiapical pathosis is an inflammatory response of the periapical connective tissue, due to a pulpal irritant.

Etiology:
1) **Pulpal inflammation**, extending from the root canal to the periapical tissue, across the apical foramen.
2) **Pulp extirpation** creates a wound, due to tearing of tissue causing inflammation of the periapical tissue.
3) **Over-instrumentation**, as a result of inaccurate measurement of root canal length.

4) **Improper manipulation:**
- **Pushing** some **chemicals** into the R.C. and surrounding periapical tissue.
- **Pushing toxic material** or remnants of dentin or pulp into the periapical area.

5) **Incomplete removal of the pulp tissue:**
Infected remnants extended to periapical tissue.

Classification of Pulpoperiapical Pathosis:

Symptomatic	Asymptomatic
Acute apical periodontitis (incipient stage)	1) Chronic apical periodontitis(incipient stage)
1) **Acute apical periodontitis (advanced stage)**	2) **Chronic apical periodontitis(advanced stage)**
a) Acute periapical abscess b) Recrudescent (phoenix)abscess c) Subacute periapical abscess	a) Chronic periapical abscess b) Periapical granuloma c) Periapical cyst
	3) Condensing osteitis.

Symptomatic Puloperiapical Diseases

Definition:

An inflammatory response of the periapical C.T., due to pulpal irritation, in which exudative forces are hyperactive and play a dominant role.

Sequel of events (pathogenesis):

1) The **irritant** passes from the pulp to the **periapical tissue**.
2) **Vasodilatation** and extravasation of fluid, increase intraperiapical pressure. **(subliminal pressure)**
3) Tooth is pushed a little bit occlusally, stretching of periodontal ligaments.
4) Sensation of tooth elongation and pain.
5) **Biting on the tooth relieves pain**, due to blood driven away of dilated blood vessels and decreases pressure.
6) If the irritant persists, **prolonged vasodilatationis followed by:**
   - inflammatory exudate
   - leucocytic infiltration
7) The tooth becomes more tender as the process advances towards the next stage, which is: **ACUTE PERIAPICAL ABSCESS**
8) **The cells of the periapical tissue suffer** from:
   - anoxia, hypoxia, necrosis, autolysis, release of proteolytic enzymes and proteolysis leading to pus formation. **(all are internal irritants)**

In the advanced stage:

9) **Agglutination of the extravasated fluid and pus and hence** biting on the tooth will increase the pain.
10) **Pus stimulates the osteoclastic activity** leading to resorption, penetration of the cortical bone, pus becomes submucosal and swelling appears.

TYPES:

1) **Acute apical periodontitis (incipient stage):**

I) **History and visual examination:**
History of:
- trauma
- old carious cavity
- crown preparation.

II) **Signs and symptoms:**
   a) Severe pain.
   b) Pain is localised, due to the presence of proprioceptors in the periodontal ligament.

III) **Percussion:** Pain increases on percussion.

IV) **Vitality test: If pulp is vital as in case of acute pulpitis with apical periodontitis (see the previous response in acute pulpitis)**

V) If pulp is **necrotic** or removed, negative response

VI) **Palpation and mobility:**
Palpation, no swelling
Mobility, immobile

VII) **Radiography: Normal or** slight widening of the lamina dura, which increases with time.

Treatment:

Root canal treatment.

N.B.: In case of **acute pulpitis with apical periodontitis**, signs and symptoms of both conditions will be shown.

It is considered the **most difficult condition to be treated**, considerable time must be given in the first visit, because:

- The **depth of anaesthesia** is a common problem.
- **Inflamed tissue must be removed from the apical portion of the canal** (pulpectomy) in order to assure complete pain relief.

2) **Acute periodontitis (advanced stage):**

Some features are the same as in the incipient stage, except for the throbbing pain which increases
- with biting on the tooth and at night.

a) **Acute periapical abscess:**

Definition:

Advanced exudative and severe symptomatic inflammatory response of periapical C.T. It is caused by contaminants from the R.C., that cause an increase in:

- **inflammatory exudate**
- **leucocytic infiltration**
- **suppuration**

Sequel of events (pathogenesis):

see before

Diagnosis:

I) **Visual examination and history:**

a) **Redness and hotness** of the mucosa opposite to the periapical region of the affected tooth.

b) **Swelling** of the oral mucosa and skin is noticed later.

Signs and symptoms:

a) Severe throbbing pain increases with biting or at night.

b) Feeling of fullness or elongation of the tooth.

c) The patient suffers from fever, malaise or loss of appetite.

N.B.:

- **The most intense pain occurs, as the pus penetrates the outer plate of bone** and **begins to raise the periosteum.**
- Once **the periosteum and mucosa rupture, due to:**
- pressure of the suppurative material,
- operator's scalpel,
- the pain subsides and will not return unless the drainage is blocked.

II) **Percussion:** Severe pain on percussion (patient wouldn't let you touch it)

Palpation and mobility: **- Palpation;**

a) No swelling in the early stage, but firm pressure against the mucosa over the root end gives +ve painful response.

b) Resorption of overlying cortical bone and localization of the suppurative mass beneath the mucosa with palpable fluctuant swelling.

- **Mobility,** slight mobility.

III) **Vitality tests:**

-ve result, because the pulp is necrotic.

IV) **Radiographically:**

Normal or slight widening of the lamina dura.

Treatment:

Root canal treatment, access cavity should be done as soon as possible, to allow drainage of the pus and relief of pressure. If drainage cannot be done through R.C.; **INCISION and DRAINAGE.**

b) **Recrudescent abscess (Phoenix):**

Definition:

Acute exacerbation of a chronic lesion (Phoenix: breaking out anew). **Phoenix** is a **bird from the Greek myth, it was said to come out from the ruins of a burnt down city.**

Etiology:

It develops as a **granulomatous zone,** which becomes contaminated or **infected** by **elements from the root canal,** as during endodontic procedures.

So micro-organisms or remnants of dead tissues move from pulp to the periapical tissue causing irritation and acute stage occurs.

Diagnosis:

All steps are similar to acute periapical abscess, EXCEPT FOR a large well defined radiolucent area.

Treatment:

Same as acute periapical abscess.

c) **Subacute periapical abscess:**

Definition:

This is a painful phase of a chronic periapical abscess cycle.

Etiology:

Blockage of the drainage of a sinus, e.g.

- Temporary filling.
- Coagulated material in sinus tract.

N.B.: In chronic abscess there is no pain, because there is drainage through the stoma.

Signs and symptoms:

- Mild to moderate pain.
- Red ballooning out (gum boil) opposite to the area of drainage.

Asymptomatic Pulpoperiapical Pathosis

Definition:

Any reaction of the periapical tissue to inflammation, where proliferative forces are hyperactive and play a dominant role.

N.B.: If irritant is of **low intensity**, the chronic periapical response may develop from the onset or it may develop from an **acute apical periodontitis** whose acute features have dissipated.

Types:

1) **Chronic apical periodontitis**

a) Chronic periapical abscess:

This long standing low grade inflammatory reaction of the periapical C.T. to pulpal irritants, is characterised **by the formation of pus draining through the stoma of a sinus tract.**

It develops from chronic apical periodontitis or acute periapical abscess, that found a pathway for drainage through the mucosa.

I) **History and visual examination:** History of long standing caries or trauma.

II) **Signs and symptoms:** Painless

III) **Percussion:** -ve or slight discomfort

IV) **Palpation and mobility: may be some degree of mobility, due to bone loss.**

V) **Vitality tests:** -ve

VI) **Radiographically: Ill-defined** (hazy) **radiolucent area around the apex.**

Different from cyst and granuloma, by the presence of ill defined radiolucency (hazy margin).

Treatment:

Root canal treatment.

Mild painful symptoms occur when sinus tract is blocked (e.g. by epithelial overgrowth) and pressure will build up by formation of pus and ballooning occurs beside sinus (gumboil). This is **subacute periapical abscess.**

b) Periapical granuloma:

- **Characterized by growth of granulomatous tissue and presence of chronic inflammatory cells.**

Sequel of events:

Irritant pass from pulp to periapical tissue lead to:

A) **Zone 1 (zone of necrosis):**
Necrotic material and sometimes microorganisms from pulp to periapical tissues.

B) **Zone 2 (zone of contamination):**
Contaminated material from zone1 and some inflammatory cells.

C) **Zone 3 (zone of irritation):** Consists of granulation tissue without micro-organisms.

D) **Zone 4 (zone of stimulation):**
Stimulation of fibroblasts at the periphery of zone 3, fibrous capsule, stimulation of osteoblasts and bone formation.

- **All** diagnostic features **are the same as in chronic periapical abscess except**
- **Radiographically**: Well-defined radiolucent area surrounded by radio-opaque margin.

Clinically no sinus tract is present.

c) Periapical cyst:

Definition:

A periapical granuloma with a central fluid-filled epithelial lined cavity.

Pathogenesis:

1) **Irritation** of the epithelial clusters (**epithelial rests** of **Mallassez**) in the periapical **granuloma** (epithelial rests of Mallassez are from epithelial root sheath of Hertwig).
2) **Epithelial cells** undergo mitosis and proliferate.
3) **Epithelial cells** do not have its own blood supply, but depend in its **nutrition** on the **surrounding granulation tissue.**
4) **Central cells** become **far away** from blood supply.
5) C.T. of the **granuloma**, gives out **finger-like processes** into the epithelium, to try to increase the blood supply.
6) The **blood supply** is **still not enough**, so **fatty degeneration** of the **central cells** and release of fluids takes place.
7) **Surrounding cells** take up fluid and undergo **spongiosis**.

8) These **cells loosen** and fall into the centre of the cavity, which increases the osmotic pressure in the center.
9) A **definit central cavity develops**, containing fluid and numbers of cells in different stages of degeneration.
10) **Fluid** from the **surrounding granulomatous tissue** is attracted to the center of the mass, because the **cyst wall** acts as a **semi-permeable membrane** and protein of dead cells elevate osmotic pressure.
11) **Cystic growth** causes **pressure** on surrounding C.T., producing ischemia and so more epithelial cells die and the **cavity increases in size**.
12) **Cystic growth occurs** on the **expense** of the **bone** as it stimulates **undifferentiated** mesenchymal cells to form **osteoclasts** and bone **resorption** takes place (**egg shell crackling**).
13) Around the cyst there is a thick layer of bone (condensing osteitis).

Diagnosis:

I) **History and visual Examination:** History of periapical granuloma, due to pulp affection by caries or trauma.

II) **Signs and symptoms:** Painless or slight discomfort.

III) **Percussion:** -ve or slight discomfort.

IV) **Palpation and mobility:**
-Palpation; swelling, egg shell crackling.
- Mobility; increased mobility, due to bone resorption and may reach root of the neighboring teeth.

V) **Vitality tests:**-ve result or false +ve in case of liquifactive necrosis.

VI) **Radiographically:** Well defined periapical radiolucency, surrounded by a radio-opaque margin.

VII) **Treatment:** Root canal treatment + surgical removal of the cyst + apicectomy.

3) **Condensing osteitis:** (pulpoperiapical osteosclerosis)

(A) It is a **productive response** of the **periapical bone** to a low grade long standing **pulpal irritation**.

(B) Characterized by high **density** of **bone**, not because of concentration of minerals, but because of **osteoblastic hyperactivity**.

(C) So increase **bone formation** at apex in expense of bone marrow space, which decreases.

(D) **Radiographically** appears radio-opaque.

(E) **Treatment** by root canal treatment, condition subsides.

AAE Consensus Conference Recommended Diagnostic Terminology

Pulpal	
Normal pulp	A clinical diagnostic category in which the pulp is symptom-free and normally responsive to pulp testing.
Reversible pulpitis	A clinical diagnosis based on subjective and objective findings indicating that the inflammation should resolve and the pulp return to normal.
Symptomatic irreversible pulpitis	A clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing. Additional descriptors: lingering thermal pain, spontaneous pain, referred pain
Asymptomatic irreversible pulpitis	A clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing. Additional descriptors: no clinical symptoms but inflammation produced by caries, caries excavation, trauma.
Pulp necrosis	A clinical diagnostic category indicating death of the dental pulp. The pulp is usually nonresponsive to pulp testing.
Previously treated	A clinical diagnostic category indicating that the tooth has been endodontically treated and the canals are obturated with various filling materials other than intracanal medicaments.
Previously initiated therapy	A clinical diagnostic category indicating that the tooth has been previously treated by partial endodontic therapy (eg, pulpotomy, pulpectomy).
Apical	
Normal apical tissues	Teeth with normal periradicular tissues that are not sensitive to percussion or palpation testing. The lamina dura surrounding the root is intact, and the periodontal ligament space is uniform.
Symptomatic apical periodontitis	Inflammation, usually of the apical periodontium, producing clinical symptoms including a painful response to biting and/or percussion or palpation. It might or might not be associated with an apical radiolucent area.
Asymptomatic apical periodontitis	Inflammation and destruction of apical periodontium that is of pulpal origin, appear as an apical radiolucent area, and does not produce clinical symptoms.
Acute apical abscess	An inflammatory reaction to pulpal infection and necrosis characterized by rapid onset, spontaneous pain, tenderness of the tooth to pressure, pus formation, and swelling of associated tissues.
Chronic apical abscess	An inflammatory reaction to pulpal infection and necrosis characterized by gradual onset, little or no discomfort, and the intermittent discharge of pus through an associated sinus tract.
Condensing osteitis	Diffuse radiopaque lesion representing a localized bony reaction to a low-grade inflammatory stimulus, usually seen at apex of tooth.

Chapter review Questions

1. Discuss the etiology of pulpal inflammation.
2. Classify pulp and periapical diseases and discuss one in details.
3. Give an account on Phoenix abscess (definition, pathogenesis and clinical/radiodraphic features).
4. Correlate histopathological changes with clinical picture in different stages of irreversible pulpitis.

References

- Hargreaves KM, Cohen S. Cohen's Pathways of the Pulp 10th ed. Mosby El Sevier, 2011.
- Ingle JL, Bakland LK, Baumgartner JC.Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- López-Marcos JF. Aetiology, classification and pathogenesis of pulp and periapical disease. Med Oral Patol Oral Cir Bucal. 2004;9 Suppl:58 62; 52 7
- Iqbal M, Kim S, Yoon F. An investigation into differential diagnosis of pulp and periapical pain: a PennEndo database study. J Endod. 2007 May;33(5):548-51.
- Gbadebo S, Akinyamoju A, Sulaiman A. Periapical Pathology: Comparison of Clinical Diagnosis and Histopathological Findings. J West Afr Coll Surg. 2014 Jul-Sep;4(3):74-88

8

Pulp and Periradicular Microbiology and Immunology

Reham Seyam
Suzan Abdul Wanees Amin

Intended Learning objectives

After reading this chapter, the student should be able to

1. Describe portals of entry of microorganisms to the pulp and periradicular tissues.
2. Describe the role of microorganisms in pulpal and periradicular disease.
3. Describe types of the predominant bacteria in pulpal and periradicular infections and their virulence factors.
4. Discuss the methods of infection control and eradication of the pulpal and periradicular infections.
5. List and identify the microbial identification technique, and describe the indications and methods for the microbial sampling of endodontic infections.
6. Describe the non-specific and specific immune reaction of the pulpal and periradicular tissues against bacteria.
7. List non-specific inflammatory mediators and discuss the role of each.
8. Understand and describe the role of immune system in inflammatory process.
9. Compare non-specific and specific inflammatory cells and mediators.
10. Describe mechanisms of microbial pathogenesis and virulence factors including the biofilm role.
11. Correlate symptomatic infections with endodontic microbiology.

Chapter Outline

Pulp and Periradicular Microbiology

- Pathways of pulp and periradicular infection
- Role of bacteria in pulp and periradicular infection
- Bacterial pathogenicity and virulence factors
- Types of flora of Pulp and Periradicular lesions
- Bacterial identification techniques
- Methods of control and eradication of root canal infection

Pulp and Periradicular Immunology

- Antigen
- Inflammatory cells
- Inflammatory mediators
- Cascade of events in immune response
- Role of immune system in inflammatory process

PULP AND PERIRADICULAR MICROBIOLOGY

I. Pathways of pulp and periradicular infection:

Micro-organisms in saliva, calculus or blood enter inside root canal through:

1. **Exposed dentinal tubules** due to caries, leaky restoration, fracture, crack, periodontal pocket, attrition, abrasion or naturally-absent cementum and enamel at cemento-enamel junction.
2. **Direct pulp exposure** due to caries, restorative procedure, fracture.
3. **Lateral canals** due to periodontal disease with deep pockets.
4. **Apical foramen** due to periodontal disease with deep pockets.
5. **Anachoresis** due to micro-organisms circulating in blood or lymph reaching an area of damaged tissues periapically.

II. Role of bacteria in pulp and periradicular infection:

- Bacteria was found to be the main cause of pulp and periradicular infection. Kakehashi et al 1965, made an experiment on 2 groups of rats; germ free and normal microbial flora rats. Pulp exposures in rat teeth were left exposed to saliva. Pulp necrosis and periapical pathosis (abscesses) developed only in rats with normal oral flora. So there is a direct role of bacteria in initiation of these pathosis.
- **Patterns of microbial colonization:**
- Organisms that infect root canals enter as **planktonic form** which is free floating single micro-organism cells in an aqueous environment inside root canal which can cause infection.
- Then, they form **aggregates** which are grouping of micro-organisms of the same species and **coaggregates** which are grouping of micro-organisms of different species.
- Bacteria then adhere to dentin surface, colonize and multiply to form biofilms.
- **Sessile biofilms** are aggregates of one or more species of bacteria in a matrix that they synthesize and that attaches the micro-organism to a solid surface (e.g tooth surface).

- **Infection in root canal:**

  Infection depends on :

$$\frac{\text{Number of micro-organisms X virulence}}{\text{Host resistance}}$$

- Selection of species inside root canal depends on oxygen tension, pH, nutrient available, virulence and microbial interaction (synergism / antagonism) and host defence.

III. Bacterial pathogenicity and virulence factors:

Bacterial virulence factors include:

1. Bacterial biofilm:

Microbial biofilms are resistant to antimicrobial agents and can not be removed by mechanical preparation alone. Inside biofilms micro-organisms have synergistic effect or antagonist effect on other micro-organisms. So, biofilms protect micro-organisms inside it; it is one of the causes.

2. Cellular components of micro-organisms:

a) Fimbrie (pilli), which allow adherence of bacteria to surfaces and allow aggregation and conjugation

b) Capsule of gram +/- ve bacteria that protects it from phagocytosis

c) Extracelluler vesicles in cytoplasm of gram -ve bacteria

- Some vesicles are secreted that have the same structure as parent micro-organisms. They will bind to antibodies produced, thus, protecting their parent micro-organisms.
- Some vesicles contain enzymes and toxins, allow bacterial adhesion, and cause heamagglutination, hemolysis, proteolytic action.

3. Micro-organisms'- secreted by products:

Micro-organisms produce and secrete acids and enzymes as

a) **Enzymes that neutralize immunoglobulins and complement systems** as Ig A protease

b) **Enzymes that aid in the spread of micro-organisms in host tissue.** They cause direct damage by degrading components of the extracellular matrix of the connective tissue.

Proteinases: breaks down proteins.

Collagenase: breaks down collagen.

Hyaluronidase: breaks down hyaluronic acid, a constituent of the ground substance of the connective tissue.

Chondriotin sulftase and acid phosphatase.

Fibrinolysin: is produced by many hemolytic streptococci. It lysis fibrin clot and is involved in the spread of the infection through tissues.

c) **Endotoxins**

It is composed of lipopolysaccharide (Lipid A portion) which is a component of the outer membrane of Gram -ve bacteria only. It is released after the micro-organism's death. It activates complement system, causes fever, shock and bone resorption. It increases in symptomatic cases.

d) **Exotoxins**

It is composed of polypeptides which are produced in the cytoplasm of Gram+ve bacteria mainly, and also in Gram -ve. It is secreted by living micro-organisms. One of exotoxins is leukotoxin which creates small holes in the leukocyte membrane causing cell lysis. Yet, it has no significant role as *F.nucleatum* in endodontic treatment does not produce exotoxin.

IV. Types of flora of pulp and periradicular lesions

Types of endodontic infection

1. **Intraradicular:** infection inside root canal. It can be divided into primary, secondary and persistent infection
2. **Extraradicular:** infection outside of root canal

1. Intraradicular:

a) **Primary infection:** The first micro-organisms which invade and colonize necrotic pulp. It is mixed polymicrobial infection, mainly containing anerobic and some facultative micro-organisms, with increase in obligate anerobes especially G-ve bacteria. Each root canal contains about 5-8 different species.

By PCR, micro-organisms identified from infected canals were mainly:

* **Firmcutes:** *Streptococcus mutans, sanginosus, intermedius* associated with smooth and pit & fissure caries

Peptostreptococcus (anaerobius) Enterococcus fecalis

* **Fusobacteria:** *Fusobacterium (nucleatum, peridonticum)*
* **Spirochetes:** *Treponema (socranskii, denticola)*
* **Actinobacteria:** *Actinomyces (Israelli, odontolyticus, naeslundii)* associated with root caries

Propinibacterium (propinicum, acnes)

* **Proteobacteria:** *Campylobacter rectus*
* **Bacteroidetes:**

Black Pigmented Bacteroids (BPB) increase in acute infection, symptomatic cases and flare ups.

Recent classification of BPB:

I) Asaccharolytic Bacteroides:

Porphyromonas (Endodontalis, Gingivalis)

II) Saccharolytic Bacteroides:

Prevotella (Melaninogenica, Intermedia, Nigrescens)

b) Secondary infection: Micro-organisms are introduced in root canals during treatment, between appointments and after root canal obturation. It consists of mixed infection as 1ry infection.

c) Persistent infection: It consists of resistent micro-organisms to irrigation and medication. They can endure nutrition deprivation, so they cause persistent or recurrent infection leading to endodontic failure. It consists of micro-organisms as primary or secondary infection but fewer species, with increase in G-ve facultative anerobic especially *Enterococcus* Faecalis (77%) and fungi *(Candida Albicans)*.

2. Extraradicular infection:

Infection in periradicular area may be caused by:

- Intrardicular infection that extends to periapical area, e.g. acute apical abscess caused by necrotic pulp, which need endodontic treatment. It contains micro-organisms similar as their intraradicular source, but with increase in Gram -ve anerobic bactereia of bacteroids as *Prevotella (denticolla, intermedia, nigrescens)* and *Porphyromonas (endodontalis, gingivalis)*

Or

- Apical actinomycosis which need endodontic surgery for its elimination.

V. Bacterial identification techniques:

Micro-organisms identification can be done with **culturing** technique or with the more recent **Moleculer methods**.

** **Culturing** is now not done routinely.

When to culture?

1. Persistent or progressive signs and symptoms.
2. Medically-compromised patients.
3. Sterility check test as teaching or research device.

Technique:

- Tooth is isolated by rubber dam.
- Tooth is disinfected to avoid contamination of oral flora.
- After access preparation, samples are taken by sterile paper points and placed in transport media that support growth of both aerobic and anerobic micro-organisms.
- Media used may be enriched blood agar or broth media (fluid thioglycolate or chopped meat broth) for facultative and fastidious anerobic micro-organisms.
- If no growth occurs this indicates sterile field.
- Disadvantages of culturing: long laboratory procedures, not all micro-organisms could be cultured and contamination of samples could occur.

****Molecular methods :**

Molecular techniques as Polymerase Chain Reaction (PCR) have been used to detect bacteria in endodontic infections.

PCR technique has allowed detection of microbes by amplification of their DNA.

But conventional PCR detects only the presence or absence of micro organisms, not their quantity. It also cannot distinguish between dead bacteria and viable one. This was overcome by Real-time PCR which detects mRNA of viable bacteria only.

VI. Methods of control and eradication of root canal infection:

* It has been well established that bacteria play a definite role in the development of pulpitis and subsequent peri-radicular periodontitis
* Consequently, a major goal of endodontic therapy is the elimination of bacteria and of tissue substrate that supports bacterial growth from the root canal system. This is by:

1. Isolation and barrier techniques: gloves, glasses, masks, shields, hand washing, rubber dam
2. Sanitation of the field, and instrument sterilization
3. Endodontic procedures to remove bacteria and their byproducts (proper chemo-mechanical preparation, irrigation with 2.5 – 5% sodium hypochlorite or 2% chlorohexidine, inbetween-visits intra-canal medicaments as calcium hydroxide, ultrasonics cleaning)
4. Endodontic procedures to prevent recontamination (3mm thick, temporary restoration e.g. Cavit or IRM, 3Dimensional obturation, permanent restoration within 30 days)
5. Sometimes, systemic antibiotics are needed.

Pulp and periradicular immunology

Immune response is the host's response to the introduction of a foreign agent. Immune system recognizes foreign substance and tries to render them harmless. The immune response starts non-specifically by inflammation, then by time, becomes a more specific immune mechanism. This is usually represented in the form of enemies and defenders.

1. Enemies (antigens)
2. Defenders (inflammatory cells and mediators)

In endodontics, the main foreign substances involved in initiating pulp and periapical tissues' response are the bacteria and their products in addition to other micro-organisms with minor roles.

Antigen

It is a foreign substance which is capable of stimulating an immune response.

Epitope or Antigenic Determinants:

It is a small area on the surface of antigen molecules which determine its antigenicity and can stimulate production or bind to antibodies.

Types of antigens:

a) **Complete antigen:** is usually protein of large molecular size that is capable of stimulating an immune response alone. e.g. micro-organisms, endotoxins.

b) **Incomplete antigen (hapten):** is usually carbohydrate of low molecular weight that is incapable of stimulating an immune response except after combination with a carrier protein (albumin).

The immune response starts non-specifically by inflammation, then, by time, becomes a more specific immune mechanism. Each type of immune response has its predominant cells and mediators.

Inflammatory cells

The main cells involved in the host immune are the white blood cells (leukocytes) which comprise:

a) Polymorpho nuclear leucocytes (PNLs):

The primary body defense cells. They are phagocytic cells that appear at acute infection.

After invasion of the tissues by micro-organisms, the PNLs leave the circulation (pavementation – adherence - diapedesis) and move towards the vicinity of the invading micro-organisms. This directional movement of the phagocytic cells is called chemotaxis (Fig. 1).

They are short lived cells, die in great numbers at acute inflammatory sites.

The accumulation and massive death of neutrophils causes tissue breakdown (pus formation).

b) Macrophages:

They are found in the reticulo-endothelial system as liver, spleen, skin, lymph nodes, bone marrow.

They reside in tissues as tissue histocytes and in blood as blood monocytes. On their activation they form macrophages.

They are mononuclear phagocytic cells that appear in chronic infection. They are considered the main link between the non-specific and specific immune responses.

Macrophages are activated by micro-organisms and their products (endotoxins), complement or cytokines.

Their main functions are:

1- Phagocytosis (Fig. 2).

2- Antigen-presenting cells

3 Secretion of various molecular mediators as the cytokines, TNF, IFN, growth factors and prostaglandins .

c) Lymphocytes:

Among the major classes of lymphocytes are:

i) **T-lymphocytes** which originate from thymus. They account for 80% of circulating lymphocytes in blood. They are subdivided to: T helper (T_h), T cytotoxic (T_c), T suppressor (T_s) and T regulaory (T_{reg}).

ii) **B-lymphocytes** which originate from fetal liver or marrow (from bursa of fabricius in birds). They account for 20 % of circulating lymphocytes in blood. They differentiate to plasma cells that synthesize immunoglobulins.

iii) **Natural killer (NK) cells** which have non specific cytotoxic activity on tumour cells, virus infected cells and graft cells.

Inflammatory mediators

There are chemical mediators that exist mainly in non-specific immune response (e.g. histamine, kinins, arachidonic acid derivatives [PGs and LTs]) and complement system) and others that exist mainly in specific immune response (e.g. immunoglobulins and cytokines).

1. <u>Histamine</u>

- It is the most important vasoactive amine that causes vasodilatation.
- It is the first mediator to act, but becomes rapidcly inactivated (has a transient action).
- It is released from mast cell degranulation. When mast cells attach to endothelium, it releases histamine that causes vasodilatation, contraction of endotheliel cells and increases intracelluler gaps for substances to pass.
- It increases in periapical lesion and inflammed pulp.
- Agents that release histamine are mechanical trauma, UV radiation, bacterial toxin, components of complement, proteolytic

enzymes from cells, peptides from PNLs, allergens.

2. **Kinins**

- It is a cascade starting from activation of Hagman factor XII (a component of blood clotting system)
- It releases bradykinin
- It is important in the delayed phase of vascular permeability, vasodilataion and pain

3. **Prostaglandins (PG) and leukoterines (LT)**

- They are produced from long chain fatty acids in all tissues, derived from arachedonic acid, synthesized within seconds in response to stimulus.
- Most cells produce them but in inflammation, they mainly come from PNLs and macrophages
- Their main functions are:
  1. They are responsible for delayed, prolonged phase of vascular permeability
  2. PG play a role in inflammation and pain in inflamed pulp
  3. PG cause bone resorption
  4. There is a correlation between increased LTB4 and PNLs and symptomatic acute periapical lesion.

4. **Complement**

- They are inactive complement proteins in circulation (Fig. 3).
- **Complement activation** is either by:
  a) **Classical pathway** initiated by antigen – antibody complex which activates C1 then C4 followed by C2 then C3 forming C3b
  b) **Alternative pathway** initiated by bacterial products (toxins) or aggregated immunoglobulins which activate C3 leading to binding of C3b to cell surface (Fig. 3).
- **Complement Cascade:** C3b activates C5 to C5b which binds to C6,C7,C8 and C9 to form the "membrane attack unit" C5b6789 which causes cell lysis cell lysis (Fig. 3).
- **Complement action:**
  i) **Inflammation**: C3a and C5a induce local vascular permeability and attract phagocytes.
  ii) **Lysis of foreign cells**: the membrane attack complex (C5b6789) creates pores in cell membranes disrupting their integrity
  iii) **Opsonization:** C3b binds to bacterial cells and serves as an Opsonin. Opsonization signals phagocytes to engulf materials including bacterial cells.

5. **Immunoglobulins (antibodies)**

- They are glycoprotein molecules produced by plasma cells. They act as a critical part of the immune response by specifically recognizing and binding to particular antigens, such as bacteria or viruses and aiding in their destruction (for more details, see next section).

6. **Cytokines (lymphokines)**

- They are a broad and loose category of small proteins (~5–20 kDa) that are important in cell signaling. They are released by cells and affect the behavior of other cells (for more details, see next section).

Cascade of events in immune response

I- **Non-specific immunity (inflammation):**

- After invasion of the tissues by micro-organisms, the **acute inflammatory cells**, the **PNLs**, leave the circulation (**pavementation – adherence - diapedesis**) and move towards the vicinity of the invading micro-organisms. This directional movement of the phagocytic cells is called **chemotaxis** (Figure 1).

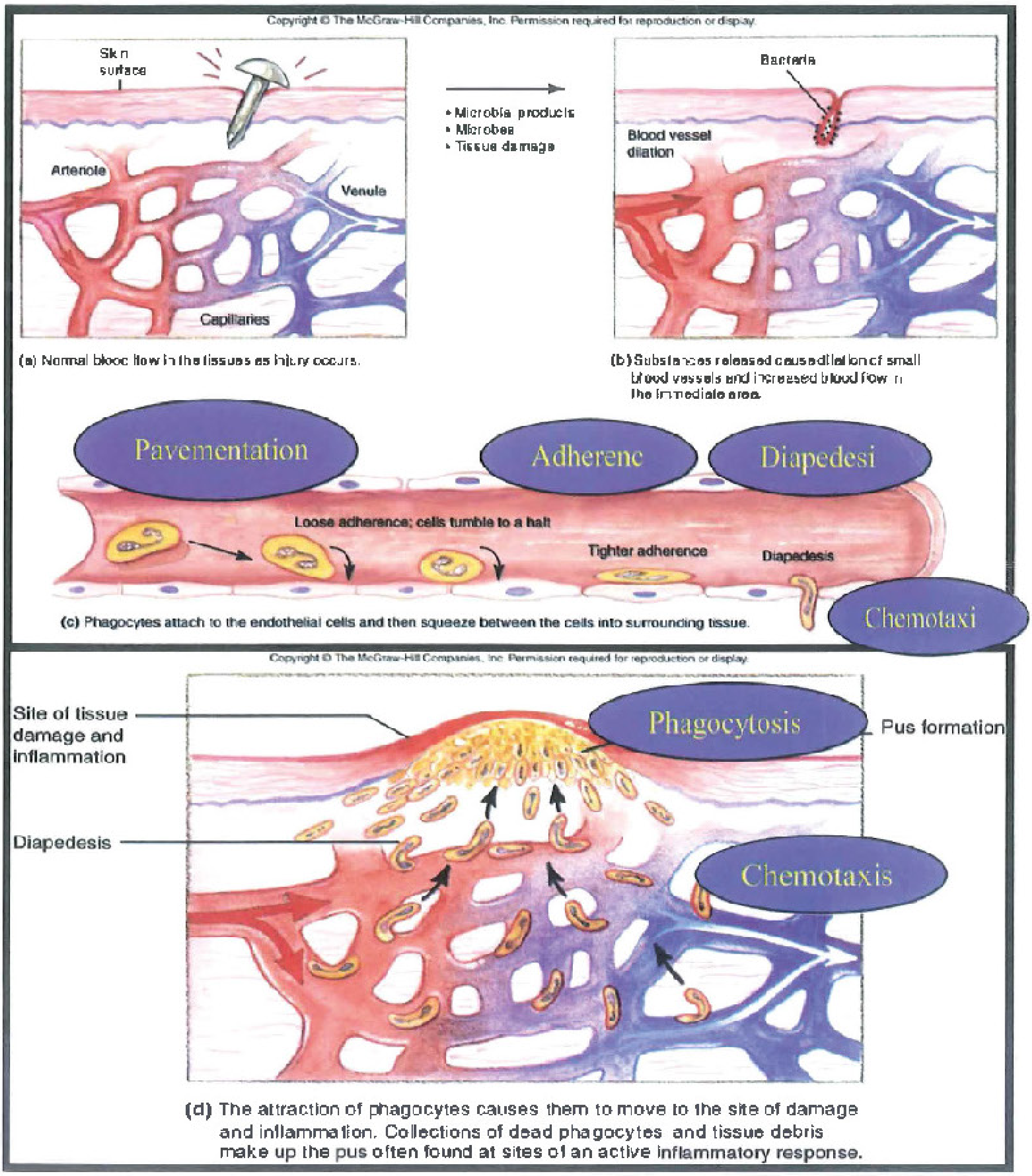


Fig. 1. Cascade of events in nonspecific immune reaction (inflammatory reaction)

- **Phagocytosis:**

  At the site of infection, the micro-organism is engulfed in **phagosome** inside the phagocytic cells (PNLs). The phagosome binds to lysosomes forming **phago-lysosomes** where micro-organism is killed or digested by intracellular degradation (Fig. 2).

- **Intracellular degradation** (intracellular killing, zapping) has two mechanisms:

  1. **O2 dependent:** (respiratory burst) where it produces oxygen free radicals to kill micro-organisms.

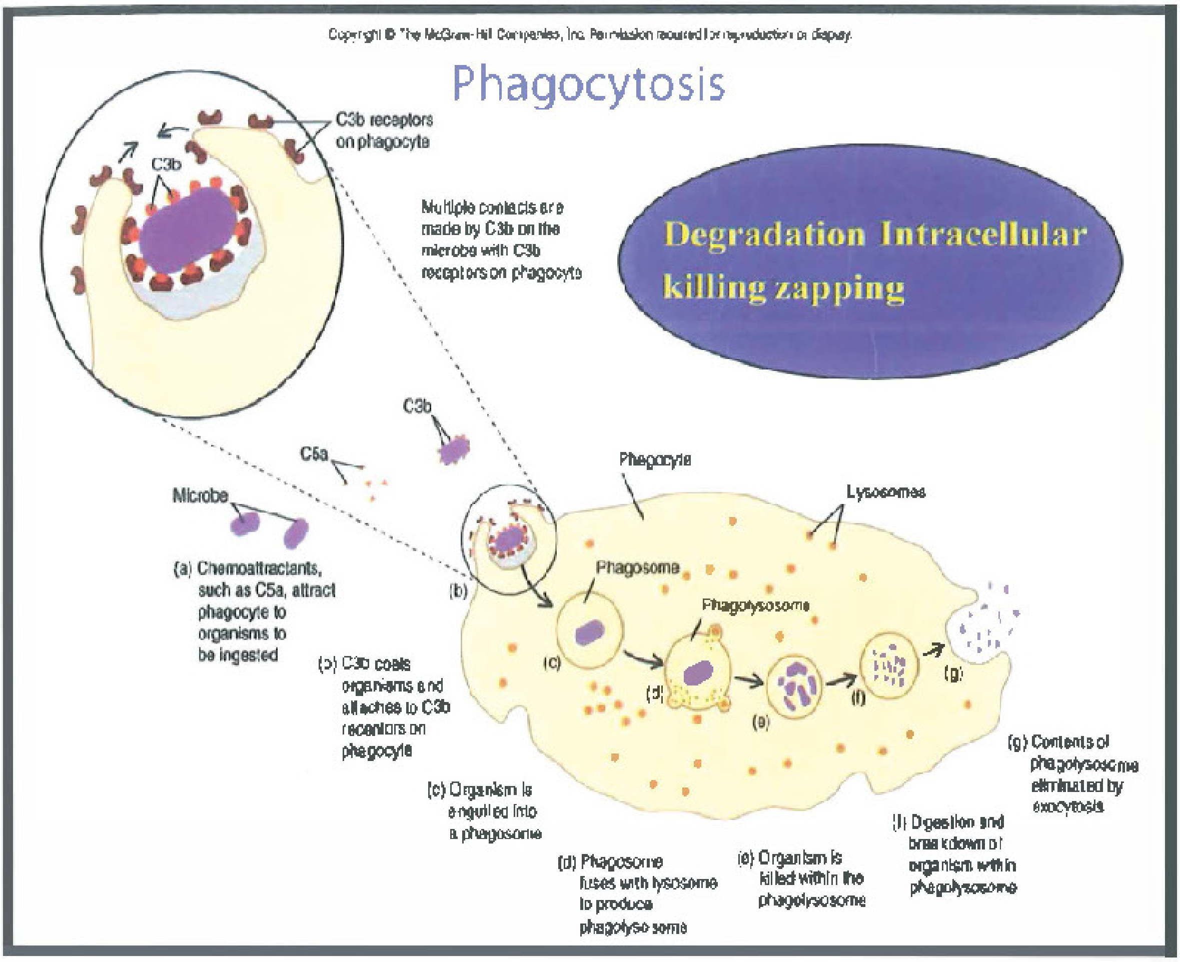


Fig. 2. Steps of phagocytosis (intracellular killing)

2. **O2 independent:** where degranulation of lysozomes with release of their contents (lysozomal enzymes) will digest micro-organisms.

- If organism virulence is high or host resistance is weak, the infection becomes chronic with stimulation of **chronic inflammatory cells** mainly the **macrophages**. They have similar function in **phagocytosis** But they also act as **antigen presenting cells** for stimulation of the **specific immune system** mainly the lymphocytes.
- The complement system has an integral role in the cascade of the non-specific immune response (inflammatory response) through different mechanisms (See previously)(Fig. 3).

II- Specific immune response

* Activation of cells of specific immune response (T- and B- cells) requires antigen-presenting cells + antigen + lymphoid system interaction at infection site or at lymphoid tissue (lymph node draining site of infection).

* Antigen-presenting cells (APC) phagocytose antigen and process antigen by its partial degradation exposing its epitope. The epitope is re-excreted on APC surface with one of major histocompatibility complex (MHC) that stimulates differentiation of certain lymphocytes either B- or T- cells or one of their subgroups.

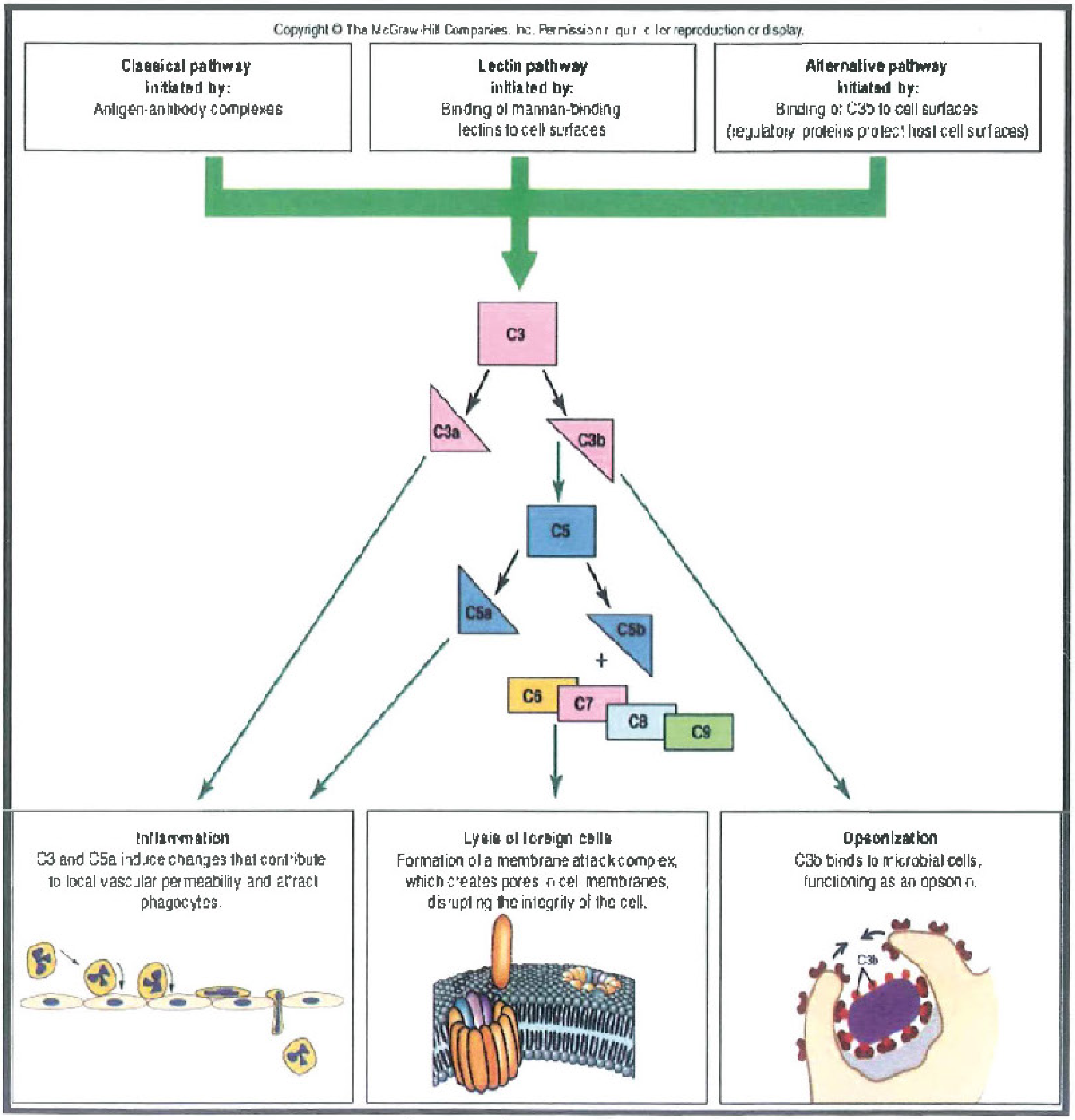


Fig. 3. Cascade of events of the complement system activation.

If MHC class II is presented on APC, it stimulates T-helper cells activation. If MHC class I is presented on APC, it stimulates T-cytotoxic cells activation.

Types of specific immune response:

1. Cell mediated: T Cells differentiate to

T helper (T_h), T cytotoxic (T_c), T suppressor (T_s) and T regulatory (T_{reg}). that produce lymphokines.

a) T helper (T_h) enhances immune response. TH cells are the maestro of the immune system.

It secretes factors which help other cells to perform their function:

1. Factors which stimulate B cells. (T_{h2} activation)

2. Factors which stimulate macrophages. (Th1 activation)
3. Factors which stimulate Tc.
4. Release lymphokines (cytokine).
5. Stimulate Clone of Memory T cells.

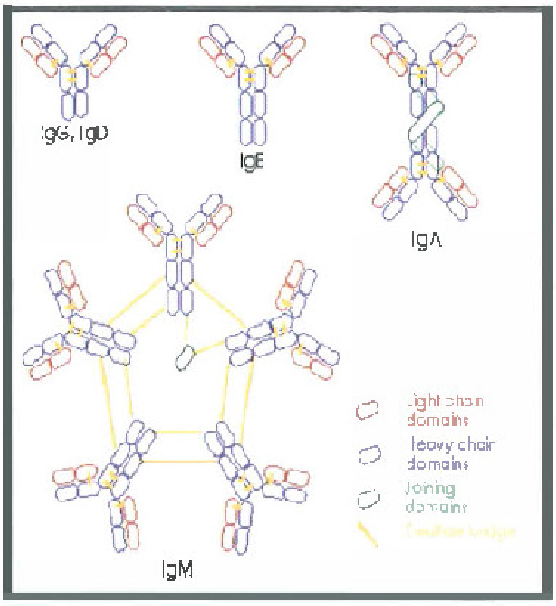


Fig. 4. Types of immunoglobulins

b) **T suppressor** (Ts) suppresses immune response

c) **T cytotoxic (Tc)** has cytotoxic effect on infected host cells and produces lymphokines.

d) **T depressor (Treg)** produces lymphokines which affect macrophages, antigen and alter inflammatory reaction.

Examples of produced **lymphokines**:

i. **Lymphotoxin:** has direct lethal effect on bacterial cells.

ii. **Macrophage activating factor:** activates macrophage.

iii. **Migration inhibiting factor:** holds macrophage in area of response.

iv. **Osteoclast activating factor:** causes bone resorption in periapical lesions.

v. **Eosinophil chemotactic factor of anaphylaxis:** call eosinophils to area of inflammation.

2. Antibody-mediated (humoral response):

B- Cells differentiate to plasma cells that synthesize immunoglobulins.

Humoral response requires B-cells + APC-Ag complex + Thelper to differentiate into plasma cells producing **Immunoglobulins (Antibodies)**

Immunoglobulins produced are of five types Ig G, M, A, D, E (Fig. 4).

a) **IgM** is a pentamer. It is the first Ig made by fetus and B cells. It appears in primary immune response. It has a short life. It is present in colostrum and mother milk to protect newly born. It fixes complement, cause agglutination and is cytolytic.

b) **IgG** is a major serum Ig 75%. It is a monomer. It appears in secondary immune response. It is the only placental transfer Ig. It fixes complement, causes opsonization to enhance phagocytosis, an antitoxin and is involved in antibody dependent cellular cytotoxicity.

c) **IgA** is found in serum (monomeric) and body secretions (dimeric): Tears, saliva, gastric and pulmonary secretions. It is a major secretory Ig on mucous surfaces to give local immunity by coating bacteria or viruses preventing their adherence to mucosal cells. It does not fix complement (unless aggregated).

d) **IgD** is present in very small amounts in serum (monomer). It is found on B cell surface. It may function as an antigen receptor.

e) **IgE** is the least common serum Ig (monomer). It binds to basophils and mast cells (complexed with Ag binding) causing allergic and hypersensitivity reactions (type I)

Immunoglobulins functions:

1. Specifically bind and agglutinate or precipitate antigen, and/or allow its phagocytosis
2. With complement, it can enhance inflammation to destroy antigen
3. Ig M and G circulating constitute 80-85% of serum Ig
4. Ig A maintains stable relation between host and normal flora and has a protective function.

But if canals are left open, this increases **sIgA** which activate rests of mallassez in periapical tissues by epithelium growth factor present in saliva, that might cause **periapical cyst**

The cascade of main events in the specific immune response is shown in Figure 5.

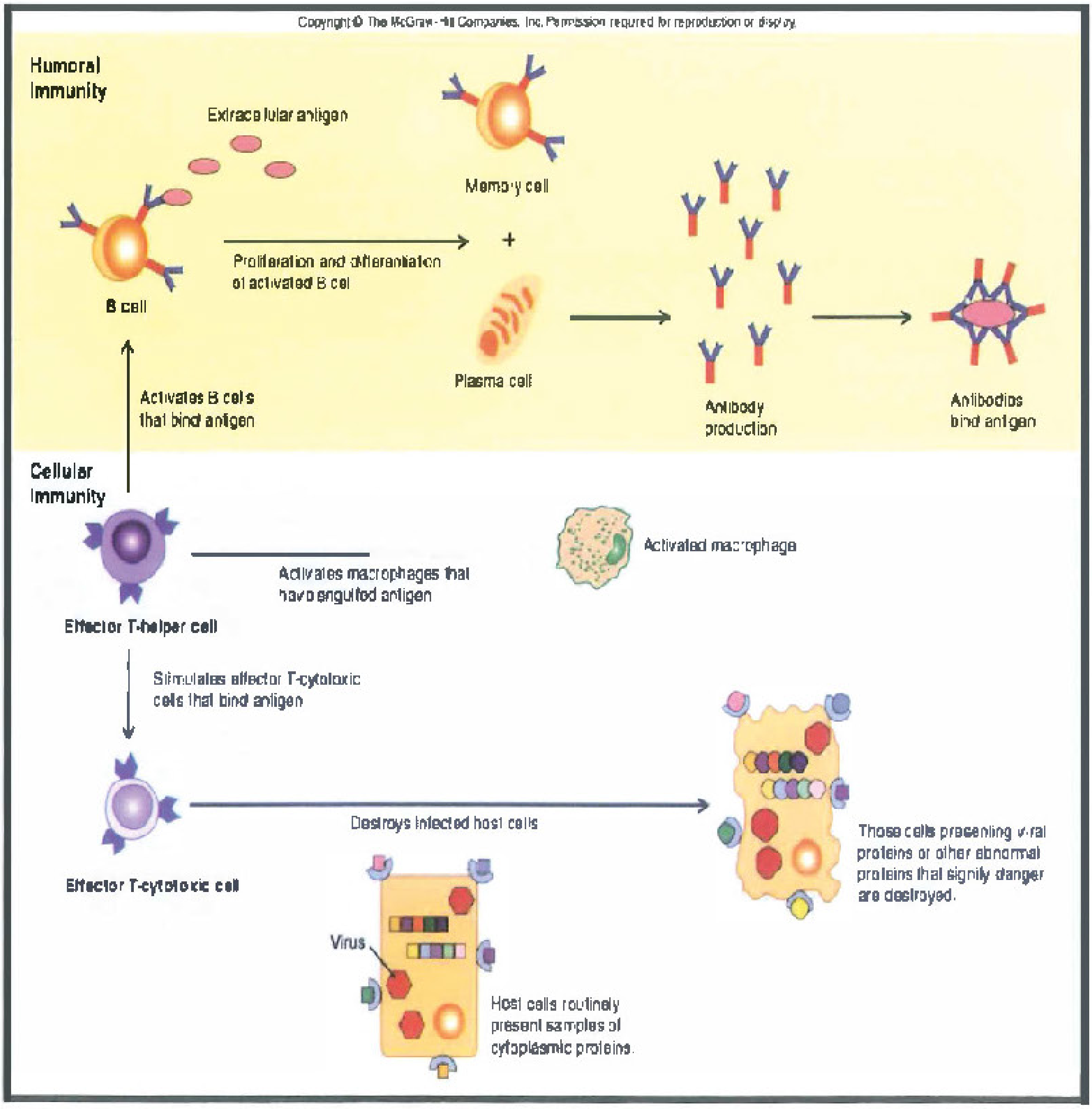


Fig. 5. Cascade of events in specific immune reaction

Role of immune system in inflammatory process

1. Protective mechanism.
2. Augment and enhance inflammation.
3. Self-destructive (allergy and hypersensitivity) (Fig. 6).

In dental practice, 2 types of hypersensitivity are important:

a. **Immediate:** It occurs within seconds or minutes. It is caused by interaction with specific IgE (humoral immunity) e.g. anaphylaxis

b. **Delayed:** It takes days to occur. It is caused by cell-mediated immunity via previous sensitization by antigen e.g. contact dermatitis.

	Type I	Type II	Type III	Type IV		
Immune reactant	IgE	IgG	IgG	T_H1 cells	T_H2 cells	CTL
Antigen	Soluble antigen	Cell-or matrix-associated antigen	Soluble antigen	Soluble antigen	Soluble antigen	Cell-associated antigen
Effector mechanism	Masi-cell activation	FcR⁺ cells (phagocytes, NK cells)	FcR⁺ cells Complement	Macrophage activation	Eosinophil activation	Cytotoxicity
Example of hypersensitivity reactgion	Allergic rhinitis, asthma, systemic anaphylaxis	Some drug allergies (e.g., peniten)	Serum sickness, Arthus reaction	Contact dermatitis, tuberculin reaction	Chronic asthma, chronic allergic rhinifs	Contact dermatitis

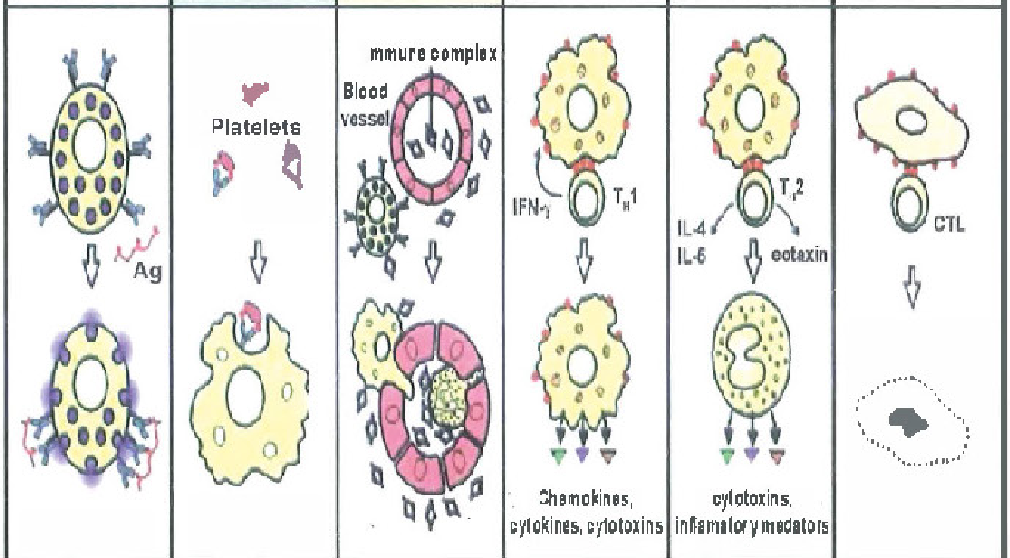


Fig. 6 Types of hypersensitivity reaction

CHAPTER REVIEW QUESTIONS

1. Describe portals of entry of micro-organisms to the pulp and periradicular tissues.
2. Describe the role of micro-organisms in pulpal and periradicular disease.
3. Describe types of the predominant bacteria in pulpal and periradicular infections and their virulence factors
4. Discuss the methods for infection control and eradication of the pulpal and periradicular infections
5. List microbial identification techniques, and describe the indications and methods for microbial sampling of endodontic infections.
6. Describe the non-specific and specific immune reactions of the pulp and periradicular tissues against bacteria.
7. List non-specific inflammatory mediators and discuss the role of each.
8. Describe the role of immune system in inflammatory process.

REFERENCES

- Ingle JI., Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10thed. Mosby El Sevier, 2011.
- Torabinejad M, Eby WC, Naidorf IJ. Inflammatory and immunological aspects of the pathogenesis of human periapical lesions. J Endod. 1985 Nov;11(11):479-88
- Narayanan LL, Vaishnavi C. Endodontic microbiology. JCD. 2010;13(4):233-239.
- Fouad AF. Endodontic Microbiology and Pathobiology: Current State of Knowledge. Dent Clin North Am. 2017 Jan;61(1):1-15.

9 Case Selection

Nihal E. Sabet

Intended Learning objectives

After reading this chapter, the student should be able to

1. List factors controlling patient referral.
2. Outline oral and dental factors affecting case selection for endodontic treatment
3. Match different factors influencing case selection

Postgraduate students should be able to

1. Sketch factors controlling patient referral
2. Point out oral and dental factors affecting endodontic case selection.

Chapter Outline

A-The Dentist Skill

i-Continuing education.

ii-Facilities and equipments

B-The Difficulty of the Case

i- **Systemic Condition Of The Patient**

Cardiac diseases
Blood disorders
Diabete mellitus
Hepatitis
Kidney Diseases
Radiation therapy
Pregnancy
Epilepsy
Tuberculosis and other lung infections
Fainting spells (Syncope)
Adrenal cortex diseases
Thyroid condition and Goiter
Menstruation
Menopause :
Allergy
Drugs and medications

ii. **The Dental Condition of The Patient**

Periodontal consideration
Surgical consideration
Restorative and prosthetic consideration

iii- **Patient Care And Eagerness**

Motivation
Economics
Age
Number of involved teeth
Occupation

The decision about whether the patient should be treated or referred to a specialist depends on different factors

a- The dentist skill

b- The difficulty of the case; this may include any of these

i. Systemic condition of the patient

ii. The dental condition of the patient

- Periodontal consideration
- Surgical consideration
- Restorative and prosthetic consideration

iii. Patient care and eagerness

All theses factors may classify endodontic cases into

1. Cases to be treated by dental practioner.
2. Cases to be referred to experienced dentist.
3. Cases to be referred to endodontist.
4. Cases should be extracted.

A-THE DENTIST SKILL

i- Continuing education: Any dentist should improve his skill by joining the programs of continuing education given by the dental schools.

ii- Facilities and equipments: The available armamentarium determines the complexity of the cases that a dentist can successfully manage in the office. Available armamentarium, therefore, will be a definite factor in case selection.

B- THE DIFFICULTY OF THE CASE

i- Systemic Condition of The Patient

There are almost no medical contraindications to endodontic therapy. However, several patient factors must be considered before endodontic treatment is initiated. The first precaution is to get an accurate and detailed medical and dental history that includes the name and telephone number of the patient's physician" Consultation with the physician is a prime requirement if any systemic conditions'. Ideally, it would be more helpful to the patient if medical problems were brought under control before endodontic treatment was started.

Cardiac diseases

In all patients complaining from a history of congenital heart disease, rheumatic fever, heart murmur, or previous valvular operative procedure, there is a susceptibility to bacteremia during dental procedures, Prophylactic antibiotic procedures to prevent subacute bacterial endocarditis should then be prescribed. In addition care must be exercised with patients using pacemakers, equipment that omits electromagnetic and electrostatic interference (eg. pulp testers, sonic devices, electrosurgical equipment ultrasonic units) may affect energy supply of the pacemaker and thereby initiate cardiac arrhythmia.

Cardiovascular disorder

In some cases, when the cardiovascular disorders have virtually disabled the patients, endodontic therapy or surgery may be completely contraindicated and only palliative treatment is possible. Other cases the patient will be on anticoagulant drugs or vasodilators. Hypertensive patients should check the physician for their tolerance for additional stress as the amount of vasconstrictor in local anaesthetics may also affect severely hypertensive patients.

Blood disorder

Haemophilia: Extraction is very hazardous for the haemophilic patient. The preferred treatment is endodontic therapy. Internal bleeding should be considered in case of haemophilic patient during administration of local anaesthetic ard injury to the gingiva during application of the rubberdam.

Others: Leukaemia, aplastic anaemia, thrombocytopoenia, platelet disorders, polycythaemia vera, and scurvy are all blood disorders that demand special attention and approval from the physician" Be sure to have the physician's consent (in writing) before prescription of drugs, especially analgesics and antibiotics.

Diabete mellitus

Before any treatment is instituted, make certain that the condition is controlled by either diet or medication. Arrange the patient's appointment time so it comes after a meal or when medication has just been taken. Blood sugar level will then be more stable. This precaution will prevent complications such as diabetic coma or insulin shock. Because epinephrine can stimulate the breakdown of glycogen To glucose, the use of local anaesthetic with a different vasoconstrictor (e.g. carbocaine with Neocobefrin) is advisable, Analgesics that do not contain aspirin are preferred because aspirin decreases the blood sugar level.

Hepatitis

Patients with a previous history of hepatitis may have viruses that remain viable in the blood stream for a considerable time after the clinical symptoms have vanished. To prevent cross contamination, discard used instruments whenever possible. If not possible, exercise extreme caution in the sterilization procedures. Be extra careful when using medications that are normally detoxified in the liver. Agents that can be used with medical clearance include aspirin, phenacetin, acetaminophen (Tylenol), mefenamic acid (ponstel), barbiturates, chlordiazepoxide (Librum), diazeprm (Valium), tetracycline, penicillin, cephalosporin, and ampicillin.

Kidney Diseases

These patients may have difficulty with the breakdown and excretion of some drugs, consequently, analgesic drug combinations containing aspirin, mefenamic acid, phenacetin, and possibly acetaminophen have been implicated in kidney disease and ought to be avoided. The use of narcotics and vasoconstrictors should be avoided as well. Since erythromycin is metabolized in the liver, it is preferable to others that are metabotized in the kidney (e.g. penicillin, tetracycline).

Radiation therapy

In patients who have undergone radiotherapy, endodontic treatment is preferred to extraction. The patient must be protected by antibiotics during the course of treatment.

Pregnancy

It is unfortunate that the need for endodontic therapy cannot be scheduled easily into the second trimester, when most physicians would prefer. The minimal use of medication coupled with lead shields will protect the foetus from radiation.

Epilepsy

An epileptic patient should take his medication prior to the appointment and should be handled gently and reassuringly. Care must be exercised while using a local anaesthetic in these patients to prevent injection into a blood vessel.

Tuberculosis and other lung infections

General manifestations of chronic lung conditions are persistent cough, haemoptysis, chest pain, fatigability weakness, loss of weight and anorexia. The dentist should not render any treatment other than palliative care, until the dis-

ease is brought under control. The blood is not sufficiently oxygenated and nutrition is impaired hence healing is retarded. Another reason for caution is that these diseases are contagious.

Fainting spells (Syncope)

It is a symptom of an extremely nervous patient who would be helped by nitrous oxide analgesia. During nitrous oxide oxygen administration, the patients will receive a high concentration of oxygen which may prevent cerebral anoxia (the cause of fainting)'

Adrenal cortex diseases

The adrenal cortex diseases are Addison's disease and Cushing's disease. In Addison's disease (low level of blood corticosteroids), the patients have poor ability to cope with stressful situations, including infection and surgery, no treatment should be performed until control has been established. Patients with Cushing's disease (high level of, blood corticosteroids), or patients who are on prolonged corticosteroid therapy often have osteoporotic bone changes, hypertension and susceptibility to bruises. There is usually an impairment of tissue healing, adjustments should be made in the corticosteroid level prior to surgery.

Thyroid and Goiter

Patients with hypothyroidism have a diminished resistance to infection and an inability to withstand prolonged stress. Antibiotics should be used during treatment. Dental appointments should be as brief and atraumatic as possible as these patients are subject to adrenocortical insufficiency. A local anaesthetic without epinephrin (Carbocaine, Citanest) should be used, premedication with sedatives (non barbiturates) is helpful.

Menstruation

During menstruation, women can have toothaches, which appears to be related to the capillary dilation that can occur. Postoperative hemorrhage occurs more frequently during menstruation than at other times. The later has been shown for pulpal extirpations. It has also been observed that there is a high incidence of flare ups during menstruation. All of these results are apparently related to hormonal changes.

Menopause

Women in the post-menopausal state can have osteoporotic jaw lesions and atypical facial neuralgia that can simulate pulpalgia. Furthermore, the periapical areas of rarefaction may not heal after endodontic therapy. This seems to be related to the depletion of oestrogen.

As long as there are no clinical signs or symptoms, no further treatment should be attempted. If these areas enlarge visibly, and/or the patient has clinical manifestations, then periapical surgery should be attempted.

Allergy

The sensitive patient may be allergic to a wide range of medications rather than to just one or two. Consult the patient's physician and use antihistamines during treatment to make the patient as comfortable as possible.

Drugs and medications

Aspirin; The most common anti inflammatory and analgesic agent. However, in the wrong circumstances it may cause systemic damage. For patients taking anticoagulants the use of aspirin may increase the effect of the anticoagulant by releasing it from its binding sites on plasmaproteins in diabetic patients taking insulin, aspirin can increases the insulin effect, and a more pronounced hypoglycemia results. Patients with a history of ulcers should not be prescribed aspirin or aspirin compounds

Corticosteriods: although corticosteroids are very effective in controlling certain chronic diseases, they have wide and far reacting side effects. Patient who is taking steroids for the control of certain conditions, such as asthma, polymyositis etc' and who exhibit the signs and

symptoms of oral infection should be supported with antibiotic coverage during endodontic treatment. The visits should be made at more frequent intervals, if possible, to shorten the duration of the antibiotic umbrella and reduce the risk of spreading infection


Fig. 1. Calcified canals

ii. The Dental Condition of The Patient

Periodontal consideration

Extensive periodontal defects may complicate the prognosis of endodontic cases. Cases with combined endodontic and periodontal lesion may dictate the combined consultation between periodontist and endodontists. It is crucial for endodontists to be aware of the periodontal factors that may influence success of endodontically treated tooth such as bone loss and clinical attachment loss. In such cases two vital factors should be considered; pulp vitality and the extent of periodontal defect (*refer to chapter endoperio*).


Fig. 2. Internal resorption

Surgical consideration

Endodontic surgery is most often decided in an attempt to improve the apical seal and correct failure of nonsurgical therapy. In certain cases clinician must decide whether nonsurgical, surgical or a combined path should follow.

- ***Root morphology***

  Malformed teeth complex and calcified canal systems, which may make the canal inaccessible, should be considered for apical surgery or intentional replantation. Fig 1

- ***Root resorption:*** several internal or external resorption that results in extensive loss of tooth substance may preclude conventional endodontic treatment and require a surgical path in addition. Fig 2&3

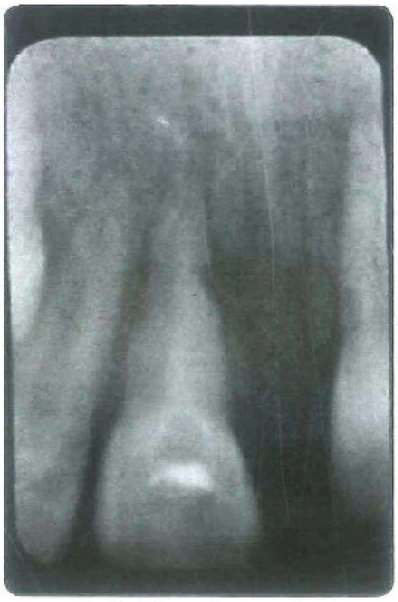


Fig. 3 External resorption

- ***Periapical condition***

Presence of an intraoral or extra oral sinus tract or a periapical lesion is not a contraindication to conventional endodontic treatment. However some require periapical surgery and curettage.

- ***Excessive crown or root damage***

The direction and location of fracture are extremely vital to endodontic prognosis. Vertical fracture presents poor prognosis for most of the cases. Teeth with horizontal fracture on the other hand can be treated by hemisectioning

- ***Root perforation***

The size and site of a root perforation are very important for the prognosis of such cases. Conventional and surgical endodontic therapy may solve the problem. However some cases of perforation are irreparable and the best line of treatment could be extraction Fig 4.

- ***Obstructions***

Foreign particles, such as amalgam, cement or separated instrument that cannot be by passed or incorporated as a part of the root canal filling, often prevent successful non-surgical therapy. Therefore apical surgery to seal the apex with amalgam should be considered to improve the long term prognosis.

- ***Predictable failure***

Teeth with developmental defects which show predictable failure should be extracted. One of these defects is the lingual developmental groove which extends along the whole length of the root surface. This defect may lead to secondary pulpal involvement due to the presence of direct communication between the apex and the gingival sulcus. Fig 5

- ***Limited accessibility***

Sometimes the access needed for the dentist's fingers and instruments to ensure success is limited, as in patients with TMJ diseases

- ***Proximity to vital structure***

Relationship, between the operative areas and adjacent vital structures, such as the mental foramen, mandibular canal, and maxillary sinus, may obstruct some surgical procedures.

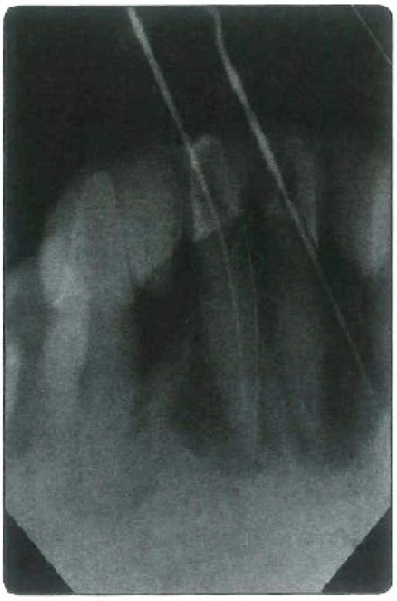


Fig. 4. Root perforation

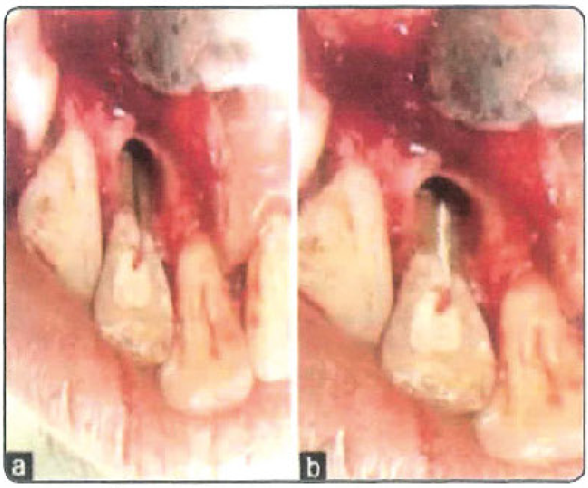


Fig. 5. Lingual developmental groove
a) before treatment b) after treatment

Restorative consideration

- ***Hypercalcification***

Calcification in the pulp chamber obscures the internal anatomy that leads to the orifices. Continued enlargement of the access cavity jeopardize tooth structure. Calcification of the root canals may cause the apex to be inaccessible by non-surgical treatment. However, chelating agents may help negotiate these calcified areas if narrow canals are located. .Fig 1

- ***Crown/root ratio***

Unfavorable crown/root ratio creates a poor prognosis. Teeth whose ratio exceeds 1:1 are most susceptible to eccentric occlusal forces.

Morphologic consideration

Endodontists should rely on recent technology to diagnose accurately the morphology of the tooth to be treated this may increase the success rate through magnifying loupes, microscope and computerized tomographic machines which may show the presence of different morphologic variations as;

*** Congenital Anomaly**

1. Dense Invaginatus

This variation in tooth morphology may be treated conventionally. In these cases where the entire root canal system is inaccessible, surgical procedure can be performed for apical seal. Fig 6

2. Taurodontism:

An inherited trait characterized by large crowns, large pulp chambers, and short roots. Roots often furcated more apically. Fig 7

*** Complex morphology**

The most common variation of normal that cause difficulty for the clinicians are the C-shaped canals, the trifurcated maxillary premolars, the furcated mandibular premolars, three rooted mandibular molars and molars with four canals"

1. Extra canals:

Tooth whose morphology includes multiple Extra canals that cannot be located, negotiated, or obturated has a poor prognosis. Apical surgery, intentional replantation, or extraction may be the alternative treatment.

Fig. 6. Dens invaginatus

Fig. 7. Taurodontism

2.C-shaped canals:

These canals are seen most often in mandibular second molars. This condition causes complex root canal morphology both longitudinally and transversely. The clinician should precurve the file carefully so the extreme curvature can be negotiated. Failure to do so will result in ledges, inadequate preparation and incomplete filling. Fig 8

3. Trifurcated maxillary premolars :

Some maxillary premolars have three roots, two buccal and one palatal. Usually the mesiobuccal canal is most difficult to file and fill and is often overlooked. Such tooth may be a contraindication to treatment by the inexperienced clinician. Fig 9

4. Furcated mandibular premolars

Furcated canals can be identified by several x-ray exposures at different horizontal angles. The level of the furcation determines the degree of difficulty to be anticipated. Canals that furcate in the middle and apical thirds present considerable difficulties during treatment. Fig 10

5. Three rooted mandibular molar

The main problem facing the clinician is locating the extra root. It is on the disto lingual, and its orifice may be more mesial than the disto-buccal orifice.

6. Four-canaled maxillary molars;

Maxillary molars, especially first molars, have two mesio-buccal canals almost 50% of the time. The exta canal is called mesio-lingual canal. It is also possible that these molars have four roots instead of three.

7. Type of the root canal:

Anatomy of the root canal system should be considered before therapy is initiated. Different techniques are employed for the wide variations in anatomy of the root canal system.

Fig. 8. C Shaped canals

Fig. 9. Trifurcated maxillary premolars

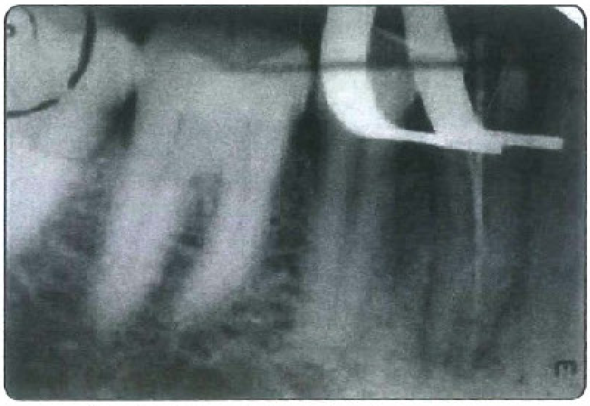


Fig. 10. Bifurcated mandibular premolars

8. Severely curved canals:

Some root canals are severely curved to such an extent that conventional endodontic treatment may virtually be impossible. Fig 11

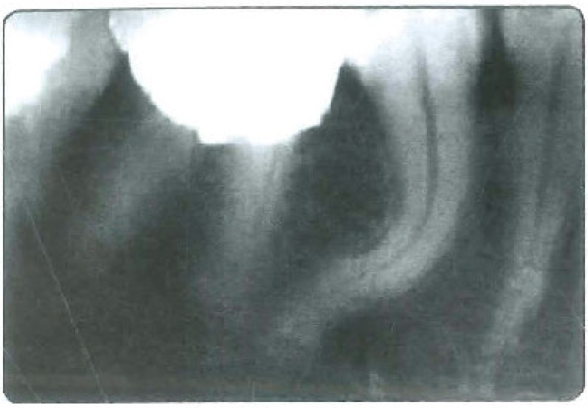


Fig. 11.S shaped canals

9. Bifurcated root canals:

These cases usually have accessible main canal and an inaccessible lateral canal. This combination creates difficulty in mechanical preparation. These conditions most commonly be seen in mandibular premolars. When the furcation occurs in the middle or apical thirds of the canals nonsurgical therapy may be impossible.

10. Immature apex

These cases require certain techniques. If the pulp was vital pulp capping or pulpotomy, with the expectation of maintaining pulp vitality until the apex would develop, certainly be the treatment of choice. If the pulp was non-vital, either apexification, or regeneration may be employed for treatment.

iii- Patient Care and Eagerness

Motivation

Patient should be aware of the importance of maintaining his teeth. Therefore education is important so that patient can realize the importance of maintaining their natural teeth functioning.

Economics

The patient should be informed that although the cost for root canal treatment may be high but the cost for extraction and prosthetic appliance is much higher .

Age

Endodontic treatment can be successfully performed in all ages. However young patient may present open apices and immature roots, old patients may presents calcifications.

Number of involved teeth

Endodontic treatment is not limited by any number of teeth and the patient may keep all the arch even after endodontic treatment.

Occupation

Some patients exert every effort to maintain their teeth as extraction may affect their phonatics and in return their occupation as singers, lawyers ... etc

All of the previously mentioned cases can be successfully endodontically treated by different modalities. Unfortunately few cases are contraindicated for endodontic treatment therefore extraction is the line of treatment for these cases:

1. Inadequate periodontal support

Careful assessment of the attachment apparatus is essential prior to considering endodontic treatment. There are periodontal conditions that preclude endodontic treatment. On the other hand, if periodontal condition is adversely influenced by pulpal conditions, endodontic therapy should be performed to improve the periodontal prognosis.

2. Condition of the remaining dentitions :

Endodontic treatment for a few teeth when the remaining dentition is healthy and intact is strongly recommended. If the patient is poorly motivated with poor oral hygiene and several missing teeth, then extraction and a removable prosthesis would be warranted.

3. Vertical fractures :

Vertical crown/root fracture cases are generally hopeless. However, fractures in the bucco-lingual plane bisecting the tooth through the furca may be corrected by retaining half of the tooth in place, or both halves may be preserved by means of bicuspidization.

4. Non restorable teeth :

The purpose of endodontic therapy is to provide a biologically acceptable sub-structure that will support the coronal portion of the tooth. If the coronal portion of the tooth is badly mutilated, or caries has extended to affect the furca or root surfaces below the bony crest[tooth extraction will be inevitable

5. Non strategic teeth :

Those teeth which have no present function or possible future prosthetic value should be extracted if signs of inflammation or infection develop.

CHAPTER REVIEW QUESTIONS

1. The skill and educational level of the dentist is a major factor affecting the success rate of his cases. Analyze this statement.
2. Two adjacent teeth may need different treatment strategy. Verify this statement
3. Patient may be the main key during establishing the treatment plan (infer)

REFERENCES

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc., 2008.
- Walton RE, Torabinejad M. Principles and Practice of Endodontics. 4th ed. W.B. Saunders Company. 2009.
- Lee KW, Lee EC, Poon KY Palatogingival grooves in maxillary incisors. Br Dent J 1968;124:14-8.
- Tronstad L. Root resorption-etiology, terminology and clinical manifestations. Endod Dent Traumatol, 1988;4:241-52.
- Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K.Outcome of primary root canal treatment: systematic review of the literature part 1. Effects of study characteristics on probability of success, Int Endod J 40:921, 2007.
- Ng YL, Mann V, Rahbaran S. Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature—Part 2. Influence of clinical factors. Int Endod J 41:6, 2008.

10 Treatment Plan

Abeer Marzouk

Intended Learning objectives

After reading this chapter, the student should be able to

1. Recognize that proper diagnosis of pulpal and periapical conditions is an essential step to determine correct treatment plan.
2. Identify emergency conditions including flare-ups that require immediate treatment and scheduling considerations.
3. Understand the relation between pulpal and periapical diseases.
4. Understand that treatment plan is affected by:
   - Patient's systemic health and severity of symptoms.
   - Complexity, maturity and procedural difficulties in the root canal system.
   - Clinician skill and time availability.
5. Identify conditions which could be treated by single or multiple visits.
6. Develop a treatment plan consisting of an appropriate endodontic and pharmacologic strategies for managing pain, anxiety and infections.
7. State the importance of follow-up visits.

Chapter Outline

- Pulp and periapical diseases
- Emergency cases
- Flare-ups
- Immature teeth
- Re-treatment cases
- Pre-medication
- Single versus multiple visits

The treatment plan signifies the planning of the management of the patient's dental problem.

To determine the correct treatment and avoid misdiagnosis, it is essential to follow a systemic approach:

1. Determine the patient's chief complaint.
2. Take an accurate medical and dental history.
3. Perform a thorough examination, including all necessary tests.
4. Carefully evaluate all necessary radiographs.
5. Analyze the results to reach a proper diagnosis.
6. Evaluate the difficulty of the case and the ability of the clinician.
7. Establish an appropriate treatment plan.

Pulpal and periapical diseases

Untreated pulpal diseases cause spread of infection from pulp to periapical tissues leading to periapical infection.

Pulp related diseases could be either classified into:

a) According to site of inflammation

I- Pulpal diseases:

1- **Vital diseased pulp**

- Acute pulpitis
- Chronic pulpitis

2- **Non-vital necrotic pulp**

II- Periapical diseases:

1- **Acute apical periodontitis** with
- vital diseased pulp or
- necrotic pulp

2- **Acute apical abscess** with necrotic pulp.

3- **Chronic apical** lesion with necrotic pulp.

OR

b) According to histological condition

I- Vital Cases:

1- **Acute irreversible pulpitis with or without apical periodontitis.**

2- **Chronic irreversible pulpitis with or without apical periodontitis.**

II-Non-Vital Cases:

1- **Pulp necrosis**

2- **Pulp necrosis with acute apical abscess**

3- **Pulp necrosis with chronic apical lesion.**

c) According to clinical condition

1. **Symptomatic.**
2. **Asymptomatic.**

Treatment plan could be determined according to different cases:

❐ **Emergency Cases**

These are cases with pain and or swelling that need an unscheduled appointment for quick treatment.

- Acute pulpitis
- Acute pulpitis with apical periodontitis
- Acute apical abscess
- Pulp necrosis

The first goal of endodontic therapy is to **relief acute pain and establish drainage of infection** either by opening the tooth or performing incision and drainage procedure.

Once the acute symptoms have been relieved, the completion of root canal treatment can be set aside, while the clinician conducts a thorough examination of the patient and develops a customized treatment plan.

❐ **Acute Vital Cases:**

Pain in such cases is due to:

Increased intrapulpal pressure leads to **acute pulpitis** which will be followed by release of inflammatory mediators and extension of the pathologic process into periapical tissues leading to **acute pulpitis with apical periodontitis**.

Treatment:

- Pulpotomy: in case of **acute pulpitis** confined to coronal pulp.

  If time permits or there is spread of infection into R.C.

- Pulpectomy: when the canals are entered all tissues have to be completely removed by instrumentation. The tooth should be closed with temporary filling in order to prevent bacterial contamination.

This is an **emergency treatment.**

- In case of instrumentation of vital tooth with a history of pain on percussion, tooth is suffering **acute apical periodontitis:**
  - The canals should be medicated with calcium hydroxide
  - Occlusal reduction is important to prevent post-operative pain.
  - Analgesics (non-steroid anti-inflammatory) should be prescribed

Scheduling Consideration

- **If a vital case** is to be treated in a single visit, adequate time must be scheduled, so that the clinician can finish comfortably the procedure.

  The patient that needs a nerve block anesthesia should be scheduled 15-20 min. before treatment.

- **If a vital case** is to be treated by multi-visit approach, the clinician should allow 5-7 days between instrumentation and obturation in order to allow periapical tissue recovery.

• Acute Non-vital Cases:

Pain or pain and swelling are the main symptoms of such cases. These cases present a microbiological challenge. A tooth that had an **asymptomatic necrotic pulp** for sometime may suddenly becomes acutely symptomatic. The cause of this dramatic change is the imbalance in the host-microbial relationship which is due to:

- Increase in the virulence of bacteria
- Changing environment of bacterial flora by simply opening the tooth.
- Reduction of host defense mechanism.

The therapeutic goals in such cases are to **reduce the bacterial content in the root canal system and promote decompression of the periapical tissues.**

Treatment:

- Instrumentation (cleaning) and copious irrigation of **necrotic pulp.**
- In case of **acute periapical abscess:**
  * Instrumentation and irrigation should be accompanied by the establishment of drainage through the root canal or incision and drainage when a fluctuant swelling exists.
  * Calcium hydroxide should be used as inter visit dressing and the tooth is sealed.

This is an **emergency treatment.**

- Antibiotics and/ or analgesics should be prescribed.
- Endodontic treatment should be completed as soon as possible to prevent bacterial penetration in the canal. Obturation is done when there is no pain, discharge or odor.

Scheduling Consideration

- To fill a **non-vital case**, it should be scheduled 1 week after instrumentation to maximize the antimicrobial effect of the inter-visit intra-canal medication.
- **Acute non-vital** cases should be seen every 24-48 hours to monitor patient progress and bring acute symptoms under control.

  Long delay between visits may lead to development of resistant microbial strains and should be avoided.

- Treating a **non-vital pulp with apical periodontitis** in a single or multiple visit has been a matter of controversy:
  - ⏭ Some researchers postulated that the inter-visit use of an antimicrobial dressing is essential to completely disinfect the root canal system.
  - ⏭ Others found no differences in success and periapical healing between treating such cases in single or multiple visits, stating that, it is possible that total elimination of bacteria may not be necessary for healing, but what matters:
- Maximal reduction of bacteria.
- Effective root canal filling.
- Satisfactory coronal restoration.

* **Flare-Ups:**

It is an acute exacerbation of a periapical pathosis after the initiation or continuation of root canal treatment, that needs an unscheduled emergency treatment.

Flare-ups occur due to variety of reasons:

- Over-instrumentation.
- Pushing dentinal and pulpal debris into the periapical area.
- Incomplete removal of pulp tissue.
- Over-extension of root canal filling.
- Chemical irritation of periapical tissues from irrigants, intra-canal medication and sealers.
- Hyper occlusion.
- Microbiologic factors.
- Root fracture.

Treatment:

- Although many of the Flare up cases could be treated pharmacologically or by occlusion adjustment, resisting cases may require re-entry into the root canal or the establishment of drainage either through the root canal or via trephination especially with non vital cases .
- The prophylactic use of antibiotics before treatment of necrotic teeth to decrease incidence of Flare-ups has been a subject of controversy.

❒ **Immature Teeth**

- **Immature permanent teeth with limited pulpal pathosis** caused by caries or trauma should receive vital pulp therapy to preserve pulp vitality, in-order to allow continuation of root formation.
- **Immature permanent teeth with necrotic pulp** could be treated by apexification to initiate root closure or tissue regeneration to allow complete root formation.

❒ **Re-treatment Cases:**

Re-treatment is required when previous endodontic therapy is failing. Although success rate of re-treatment is high, it may be lower than that of initial endodontic therapy.Before re-treatment is done, important issues should be considered:

- Cause of failure.
- Presence of procedural error.
- Accessibility for re-entry of root canal.

According to this:

- Re- treatment could be done by conventional therapy alone and/ or surgical treatment.
- The use of the operating microscope and ultra-sonics facilitates the non-surgical re-treatment in many cases that were re-treated surgically before.

- Non-surgical re-treatment is always preferable and should be attempted before resorting to surgery.
- Surgery should be planned only when practitioner is certain that the failing case was initially treated properly and can't be improved. Also, in presence of calcifications,prosthetic reasons, a large lesion or when a biopsy is needed.

❒ **Pre-medication:**

The need of pre-medication may affect the treatment plan:

- Patients with damaged or prosthetic heart valves.

  Need prophylactic antibiotics 1 hour before initiation of treatment.

- Patients with myocardial infarction:
  * Need prophylactic antibiotics before treatment.
  * Elective endodontic treatment is postponed 6 months after attack.
  * Keep the appointments short and comfortable.
- Patients with hypertension:
  * Need premedication.
  * Plan short appointments.
  * Use local anesthetic with minimum amount of vasoconstrictor.
- Patients suffering leukemia:
  * Need prophylactic antibiotic for poor healing.
  * Avoid treatment during acute stages.
- Patients under corticosteroid or anticoagulant therapy:
  * Need to adjust their dosage before each appointment.

Single Visit versus Multiple Visits:

Studies have been made to answer 2 basic questions:

1. Is single-visit endodontic therapy more or less painful postoperatively than multiple visits therapy?
2. Is single-visit endodontic therapy more or less successful than multiple visits therapy?

It has been found that there was no detectable difference in the effectiveness of root canal treatment between single and multiple visits in terms of:

- Success rate.
- Postoperative pain and flare ups.
- Short-and long term postoperative complications.

Advantages of single-visit endodontic therapy:

- It reduces the number of patient appointments specially for those who suffer fear and anxiety, for those who need premedication and for those who don't return to complete the treatment.
- It eliminates the chance for inter-appointment microbial contamination and flare ups.
- It eliminates the need of the clinician to re-familiarize the canal anatomy at the next visit.
- It allows for the immediate use of the canal space for retention of a post and construction of an aesthetic temporary crown when required.

Disadvantages of a single visit:

- Flare-ups cannot be easily treated by opening the tooth for draining.

- The long appointments may be tiring and uncomfortable for some patients that cannot keep their mouth open for a long time.

Single visit root canal therapy should be considered in the following cases:

- Vital cases without preoperative apical periodontitis.
- Fracture anterior teeth where aesthetic is of importance.
- Medically-compromised patients who need repeated regimens of prophylactic antibiotics
- Patients who are physically unable to return for a second visit.
- Patients requiring sedation or operating room treatment.

Single visit should be avoided in:

- Asymptomatic non vital teeth with apical radiolucency and no sinus tract.
- Most re-treatment cases.
- Cases where hemorrhage or exudate can't be controlled.

So, what can be done and what should be done, present two very different approaches to endodontic treatment planning:

- The patient's systemic health, severity of symptoms and level of anxiety.
- The complexity of the root canal system and the probability of procedural difficulties.
- Clinician skills and time available.

CHAPTER REVIEW QUESTIONS

1. Discuss scheduling considerations of vital cases.
2. Discuss scheduling considerations of non-vital cases.
3. Mention different causes of flare-ups and different treatment modalities.
4. Discuss multiple visit versus single visit regarding advantages and indications.

REFERENCES

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Carrotte P Endodontics: Part 2 Diagnosis and treatment planning. Br Dent J. 2004 Sep 11;197(5):231-8.
- Yeng T, Messer HH, Parashos P. Treatment planning the endodontic case. Aust Dent J. 2007 Mar;52(1 Suppl):S32-7.
- Jayakodi H, Kailasam S, Kumaravadivel K, Thangavelu B, Mathew S. Clinical and pharmacological management of endodontic flare-up. J Pharm Bioallied Sci. . 2012;4(Suppl 2):S294-S298.

2
PART

TECHNICAL ENDODONTICS

11

Pulp Space Morphology & Coronal Access Cavity Preparation

Reem A. Lutfy

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define pulp space.
2. List and describe major components of pulp space.
3. Identify, describe and illustrate different root canal classes.
4. Classify, illustrate and compare between various types of canal configurations
5. Demonstrate macroscopic anatomy for anterior, premolar and molar permanent teeth.
6. List the average length, number of roots, and most common canal types in each tooth in the oral cavity
7. Identify principles of access cavity preparation and recognize the rationale behind them
8. Identify factors affecting outline form
9. Relate the pulp space anatomy of each tooth in the oral cavity to its access cavity preparation
10. Illustrate the outline form of access cavity for each tooth in the oral cavity demonstrating the location of each orifice relative to occlusal or lingual surfaces
11. Characterize most frequent anatomical variations in pulp space morphology of each tooth and their influence on access cavity preparation
12. Summarize phases of access cavity preparation in various groups of teeth and relating them to the principles & factors governing them
13. Identify various errors during access cavity preparation
14. Analyze possible causes for such errors
15. Outline the axioms of pulp anatomy

Chapter Outline

Anatomy of pulp space

Coronal pulp space

- Pulp chamber
- Pulp horns

Radicular pulp space

- Root canal
- Accessory canals
- Apical foramen

Root canal classes

Types of root canal configurations (systems)

Pulp space morphology of anterior teeth

Pulp space morphology of premolars

Pulp space morphology of molars

Coronal access cavity preparation

Principles of coronal access cavity preparation

I- Outline form

II- Convenience form

III- Removal of remaining carious dentin and defective restorations

IV- Toilet of the cavity

Endodontic coronal access cavity preparation in maxillary and mandibular anterior teeth

Errors during endodontic cavity preparation in maxillary and mandibular anteriors

Endodontic coronal access cavity preparation in maxillary and mandibular premolar teeth

Errors during endodontic cavity preparation in maxillary and mandibular premolars

Endodontic coronal access cavity preparation in maxillary molar teeth

Endodontic coronal access cavity preparation in mandibular molar teeth

Errors during endodontic cavity preparation in maxillary and mandibular molars

A successful endodontic treatment depends mainly on proper diagnosis, thorough cleaning and shaping and three- dimensional obturation. The gate to successful cleaning and shaping is a properly designed access cavity which in turn is very much dependable on the macroscopic anatomy of the tooth.

Each tooth in the dental arch contains pulp tissue. The pulp is a connective tissue that is encased within hard tooth structure, the dentin. The *pulp space* is the central cavity within a tooth that is entirely enclosed by dentin except at the apical foramen. This space differs from one tooth to another and is subject to numerous variations and anatomic complexities that had been demonstrated in the literature. The clever clinician must always approach the tooth to be treated assuming all possible deviations and developing a 3-D image of its canal system.

The pulp space is divided into: Fig. (1):

1) *Coronal pulp space*: It is the space occupied by the pulp tissue within the crown.

a- *Pulp chamber:*

It is the pulp space that lies within the crown of the tooth. The shape of the pulp chamber usually reflects the external form of the crown. The size, on the other hand, may be reduced by aging and dentin deposition.

b- *Pulp horns:*

These are accentuations in the roof of the pulp chamber that lie directly below cusps and developmental lobes.

2) *Radicular pulp space*: It is the space occupied by the pulp tissue within the root.

a- *Root canal:*

It is the part of the pulp space that lies within the root of the tooth. It starts by an orifice and ends by an apical foramen. The root canal tapers till it reaches its narrowest diameter at the apical constriction.

b- *Accessory canals:*

These are lateral branches of the main root canal communicating the pulp space with the periodontium and ending with accessory foramina. Although they could exist at any level along

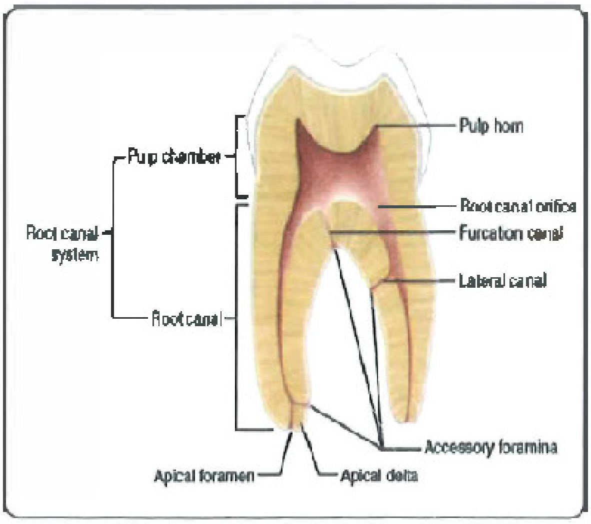


Fig.1. Anatomy of the pulp space

the length of the root canal, they are mainly detected at the apical third of the canal as well as at the furcation area in multirooted teeth. A distinction sometimes could be made between the lateral and the accessory canal in that the lateral canal is an accessory canal that branches to the lateral surface of the root and is visible on the radiograph. They could occur due to:

- The periodontal vessels at the apical third would curve around the root apex of a developing tooth and get entrapped within the epithelial root sheath of Hertwig.
- Disintegration of a segment of the epithelial root sheath of Hertwig before induction of dentin formation, hence inhibiting dentin or cementum formation.
- Failure of fusion of tongue like projections of the diaphragm in multirooted teeth resulting in accessory canals in the furcation areas. (focal canal)

In a single rooted tooth, the coronal (pulp chamber) and radicular (root canal) pulp spaces are continuous as the pulp chamber merges into the root canal and the division between them is indistinct.

The apical foramen:

It is an aperture at or near the apex of the root through which the blood vessels and nerves of the pulp would enter or leave the pulp cavity.

Anatomical studies had demonstrated that the apical foramen could be located within the anatomical apex in only 17-46% of the cases. It could also exist on the mesial, distal, labial or lingual sufaces at an average of 0.4-0.7 mm away from the anatomical apex Fig. (2).

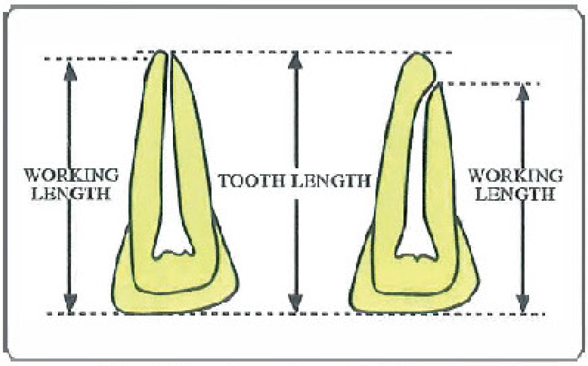


Fig. 2. Location of the apical foramen

Root Canal Classes:

Root canals can be classified according to maturity of the canals (completion of root canal formation and apical constriction) and curvature as follows Fig. (3):

Class I: Mature, straight root canals
(at least 3y after ~~dev~~ eruption = complete root development
Class II: Mature, curved root canals that could be:

apical constriction

- Slightly curved
- Severely curved (dilacerated)
- Bayonet
  S-shaped

Class III: Immature with open apex that could be:

- Tubular (late)
- Blunderbuss (early)

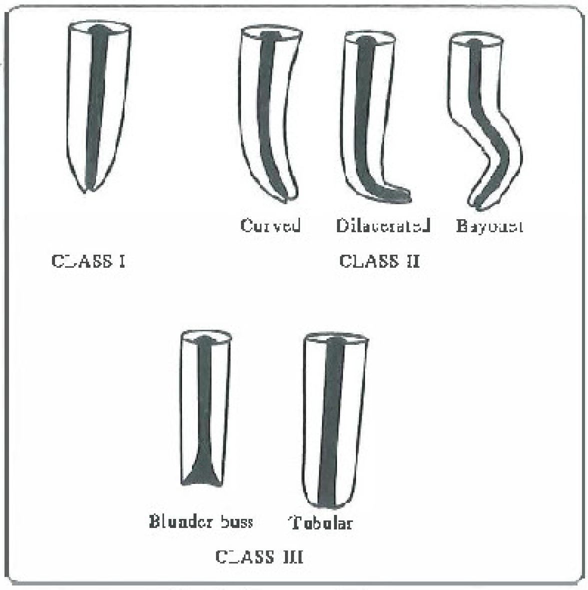


Fig. 3 Root canal classes

Types of Root Canal Configurations (Systems):

Another classification has been developed by Weine [1] to describe the different possible configurations of the root canal system within the single root Fig. (4) as follows:

Type I: Single root canal with one orifice and one apical foramen.

Type II: Two root canals with two orifices and one apical foramen.

Type III: Two root canals with two orifices and two apical foramina

Type IV: Single root canal with one orifice and two apical foramina forming an apical delta.

Type V: Single root canal with one orifice that divides into two canals within the body of the root forming a dentin island then reunite to exit with one apical foramen.

Type VI: Two root canals with two orifices that unite within the root into one canal then divide again at the apical third into two canals with two apical foramina.

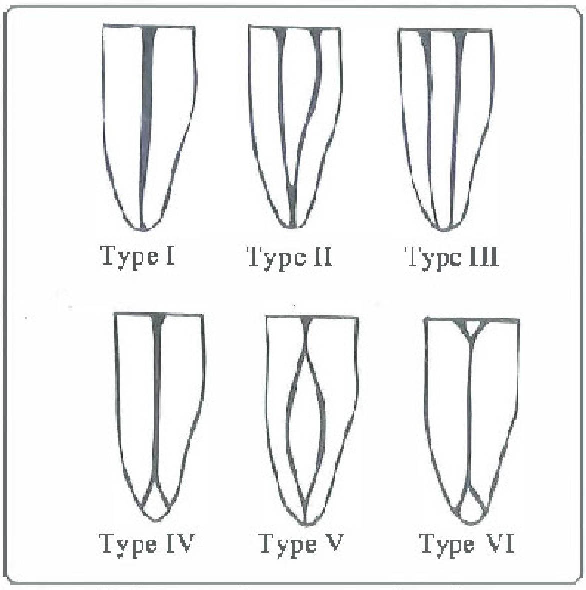


Fig. 4. Types of root canal configurations

VERTUCCI CLASSIFICATION OF ROOT CANAL MORPHOLOGY

Other studies made by *vertucci* , using cleared teeth in which the root canal systems had been stained with hematoxylin dye, found a much more complex canal system. In doing so *vertucci* identified eight pulp space configurations, which can be briefly described as follows (Fig. 5):

- *Type I:* A single canal extends from the pulp chamber to the apex (1).
- *Type II:* Two separate canals leave the pulp chamber and join short of the apex to form one canal (2-1).
- *Type III:* One canal leaves the pulp chamber and divides into two in the root; the two then merge to exit as one canal (1-2-1).
- *Type IV:* Two separate, distinct canals extend from the pulp chamber to the apex (2).
- *Type V:* One canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina (1-2).
- *Type VI:* Two separate canals leave the pulp chamber, merge in the body of the root, and separate short of the apex to exit as two distinct canals (2-1-2).
- *Type VII:* One canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally separates into two distinct canals short of the apex (1-2-1-2).
- *Type VIII:* Three separate, distinct canals extend from the pulp chamber to the apex (3)

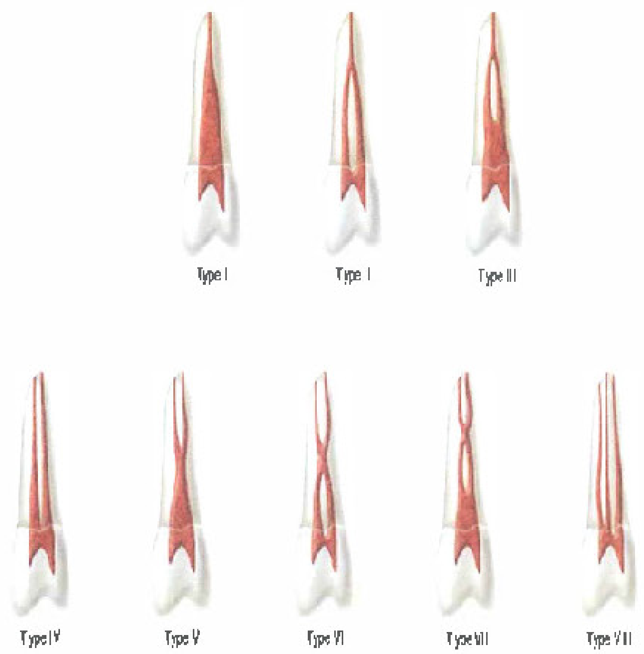


Fig. 5. Diagrammatic Representation of canal configurations based on the work of Vertucci

PULP SPACE MORPHOLOGY OF ANTERIOR TEETH

Maxillary Central Incisor:Fig. (6)

Average Length: 23mm

Root Number and Form: One and bulky

Canal Type: Type I

Labio-lingual section: It is narrow near the incisal edge then widens as it approaches the cervical line and then tapers towards the apex. Lingual shoulder is present cervically.

Mesio-distal section: The pulp chamber is wider than in labio-lingual (L-L) section with three pointed pulp horns.

The chamber tapers towards the canal which in turn tapers uniformly to the apex.

Cross Section:

Cervical: nearly triangular in shape with apex lingually and base labially.

Mid- root: ovoid mesio-distally

Apical: round

Outline form:

Triangular in the middle middle one third of thepalatal surface with base incisally and apex cervically.

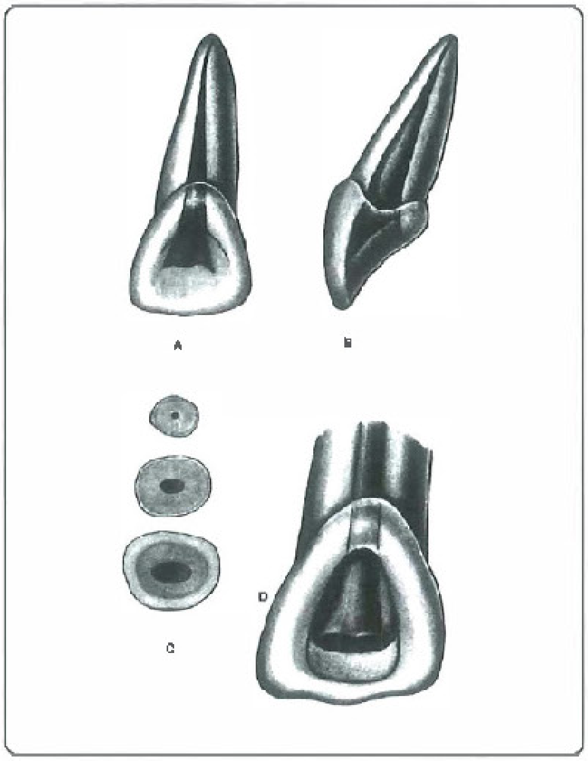


Fig. 6 Maxillary central incisor. A: mesiodistal section, B: labiolingual section, C: cross sections (cervical, middle, apical), D: outline form

Maxillary Lateral Incisor: Fig. (7)

Average Length: 22.5mm

Root Number and Form:

One slender root frequently with an apical distal and/or a palatal curvature. That's why there is palatal spread of infection

Canal Type: Type I

Labio-lingual section: Similar to maxillary central incisor. Lingual shoulder is present where the chamber and canal join.

Mesio-distal section: As maxillary central incisor.

Cross Section:

Cervical: oval in labio-lingual (L-L) direction

Mid-root: ovoid

Apical: round

Outline form: Triangular in the middle middle one third of palatal surface.

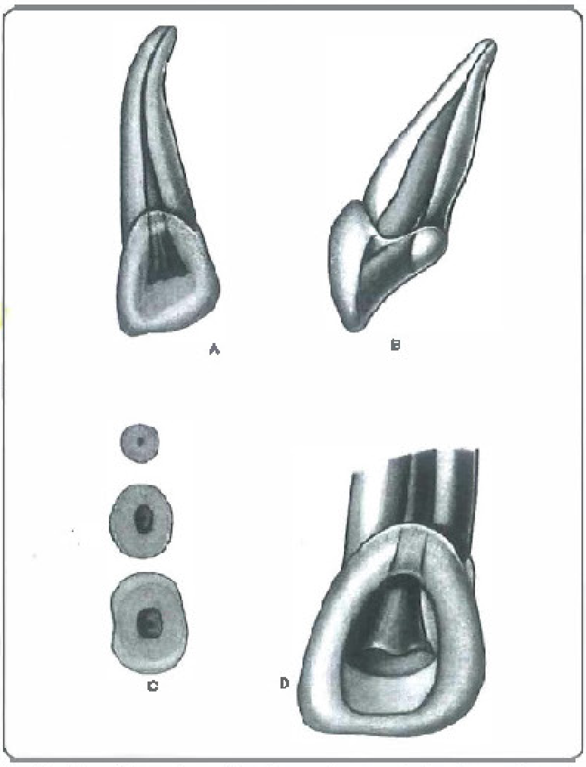


Fig.7. Maxillary lateral incisor; A: mesiodistal section, B: labiolingual section, C: cross sections (cervical, middle, apical), D: outline form

Maxillary Canine: Fig. (8)

*Average Length:*26 mm; the longest root in the oral cavity.

Roots Number and Form:

One root, slender mesio-distally and bulky labio-lingually. Distal/ labial apical curvature may be present.

Canal Type: Type I

Labio lingual section: Begins as a point incisally and widens at cervical and mid root regions with prominent lingual shoulder. The canal narrows thereafter in the apical one third as it approaches the apical foramen.

Mesio-distal section: Narrower than in the L-L section with one pointed pulp horn and a nearly uniform taper to the apex.

Cross Section:

*Cervical:*oval in L-L direction

Mid-root: oval

Apical: round

Outline form: Oval inciso-gingivally in the middle middle third of the palatal surface.

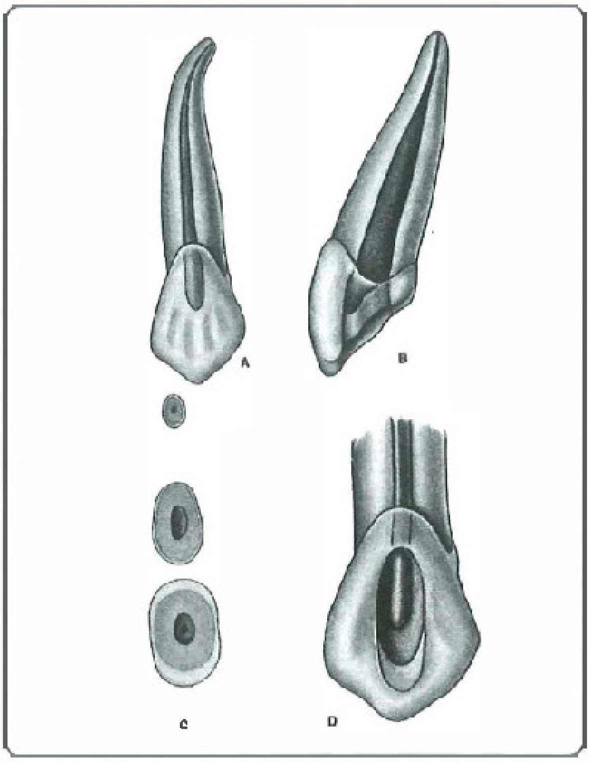


Fig. 8 Maxillary canine; A: mesiodistal section, B: labiolingual section, C: cross sections (cervical, middle, apical), D: outline form

Mandibular Central and Lateral Incisors. Fig. (9)

Average Length: 21 mm

Roots Number and Form:

One root that is narrow mesio distally (M D),but relatively broad labio-lingually (L-L). It has distal and /or lingual curvature Sometimes two roots can be found; labial and lingual.

Canal Type:

Type I 60%-70%

Type II, Type III 30%-40%

Labio lingual section: The chamber starts as a point incisally then widens. One broad canal is found or two canals (labial & lingual) that either join near apex (type II) or remain separate (type III). Lingual shoulder can be detected.

Mesio distal section: Quite a narrow pulp chamber with three pulp horns. The chamber tapers towards a very narrow canal that follows the curve of the root.

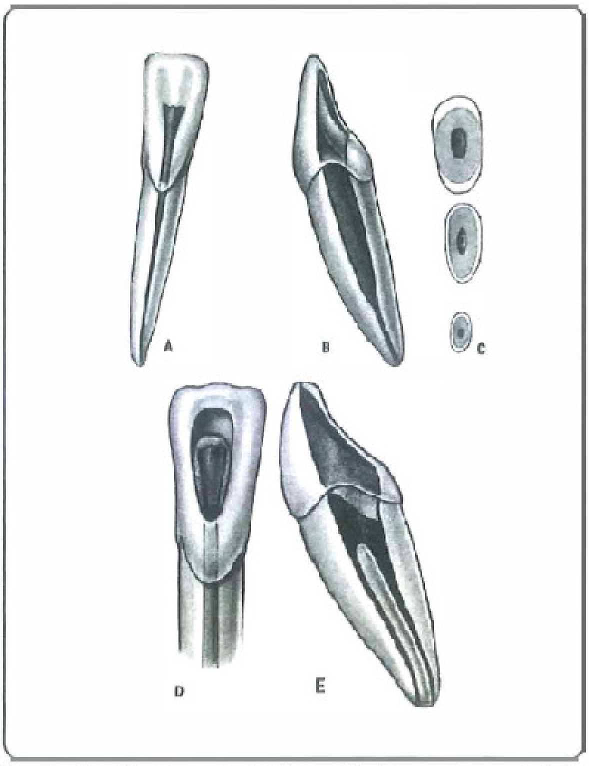


Fig. 9. Mandibular central & lateral incisors; A: mesiodistal section, B: labiolingual section (type I) , C: cross sections (cervical,middle, apical), D: outline form, E: labiolingual section (type III).

Cross Section:

Cervical: oval in L-L direction and narrow in M-D direction.

Mid-root: ovoid

Apical: round

Outline form: Triangular in the middle third of the lingual surface, but sometimes could be oval due to aging.

Mandibular Canine: Fig. (10)

Average Length: 24mm

Roots Number and Form:

One root that is narrow mesiodistally, but broad labiolingually.

Rarely, two roots found; labial and lingual.

Canal Type:

Type I 94%

Type II, III 6%

Labio-lingual section: Starts as a point incisally then widens till apical third where it starts to taper.

Mesio-distal section: Much narrower than in L L section with one pulp horn under the cusp and nearly uniform taper to the apex.

Cross Section:

Cervical: oval in labiolingual direction

Mid-root: ovoid

Apical: round

Outline form: Oval labiolingually in the middle middle third of lingual surface.

PULP SPACE MORPHOLOGY OF PREMOLARS

Maxillary First Premolar: Fig. (11)

Average Length: 21mm

Roots Number and Form:

- Two roots in most of the cases; buccal and palatal.
- One root in 38% of the cases.
- Three roots; MB, DB and palatal with an incidence up to 6% (Fig.12). This variation was found to be quite influenced by the ethnic background.

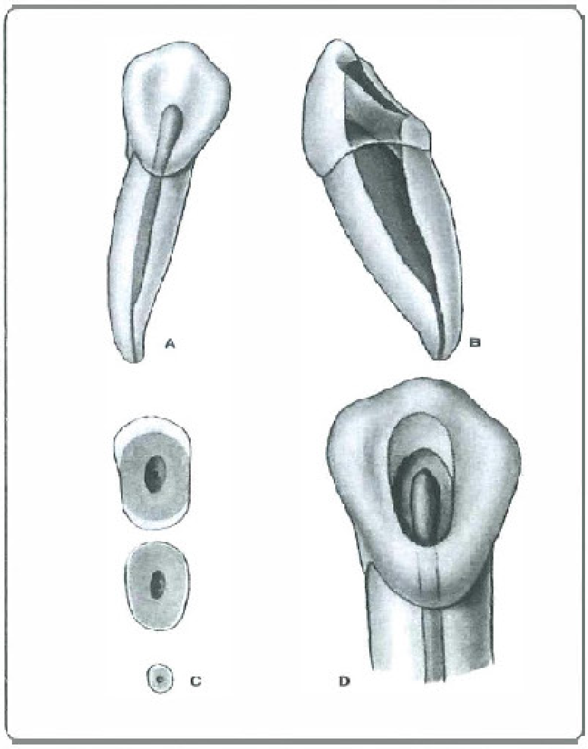


Fig. 10. Mandibular canine; A: mesiodistal section, B labiolingual section, C: cross sections (cervical, middle, apical), D: outline form

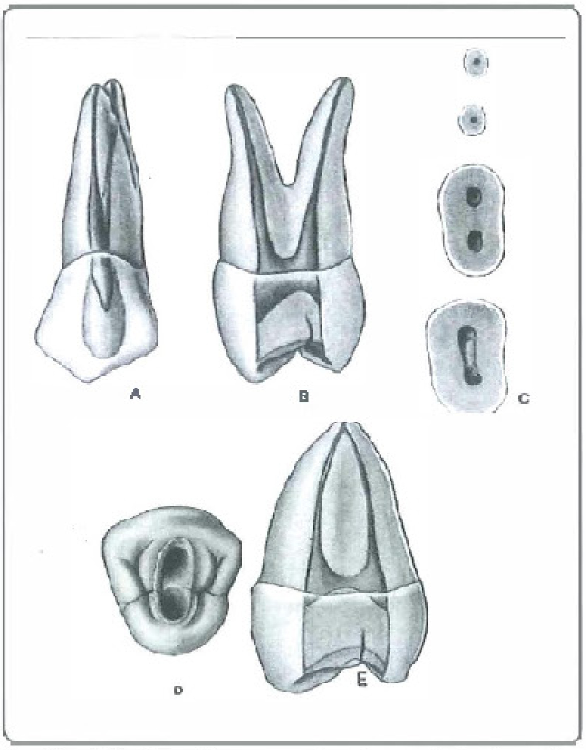


Fig. 11. Maxillary first premolar. A: mesiodistal section, B: buccopalatal section (two roots, type I each), C cross sections (cervical, middle, apical), D: outline form, E: buccopalatal section (one root, type II)

Canal Type:

The majority of maxillary premolars were found to have two canals, buccal and palatal, irrespective of whether the tooth has a single or a double root.

Two roots: Each has type I

One root : Type III most frequent

Type II less frequent

Type I the least frequent

Three roots : Each has type I (MB, DB and palatal canals)

Bucco-lingual section: Wide,two pulp horns under each cusp.

Buccal pulp horn is more prominent in young teeth. Roof of the pulp chamber is coronal to the cervical line. The floor is convex and lies deep in the coronal one third of the root below the cervical line, with two orifices buccal and palatal.

Mesio-distal section: Narrow resembling the upper canine.

Cross Section:

Cervical: oval bucco-palatally/ribbon shaped/or figure 8

Mid-root: ovoid or almost round "each canal"

Apical: round

Outline form: Oval in buccolingual dimension, in the center of the occlusal surface.

<u>Maxillary Second Premolar:</u> Fig. (13)

Average Length: 21 mm

Roots Number and Form:

One root in 85% of the cases.

Two roots in 15% of the cases

The three-rooted form is a rare finding and ranges from 0% to 1%.

Canal Type:

The maxillary second premolar has a single canal in approximately 50% i.e even though 85% of these teeth have a single root, as previously mentioned, a high proportion will still have two canals present.

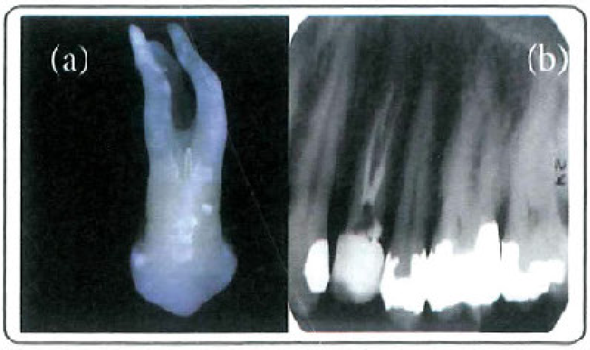


Fig. 12. a. Extracted maxillary right first premolar with three very fine roots, b. Maxillary left first premolar with three roots and three canals (MB, DB, Palatal)

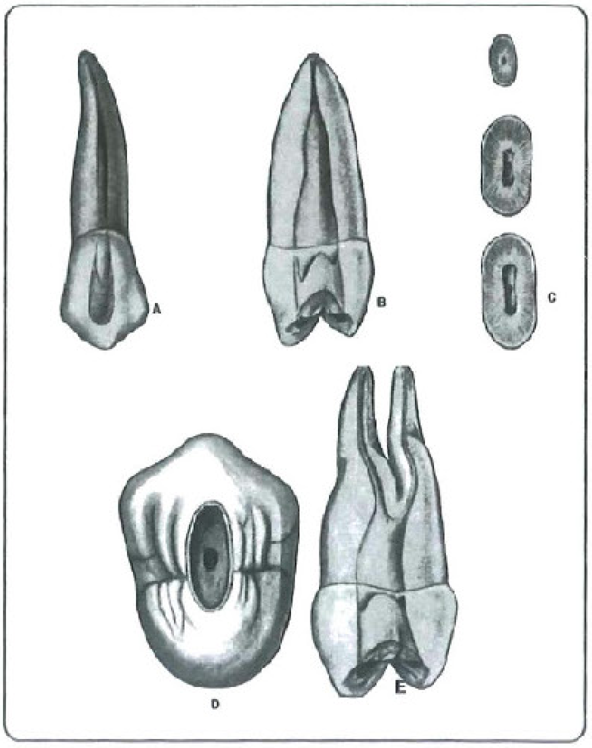


Fig. 13 Maxillary second premolar; A: mesiodistal section, B: buccopalatal section (one root with type I canal), C: cross sections (cervical, middle, apical). D: outline form, E: buccopalatal section (two roots,bayonet, each with type I canal).

One root: Type I most frequent

Type II less frequent

Type III least frequent

Two roots: Each has type I, Bayonet curve could be found in 20% of the cases.

Three roots: Low incidence of three canals in the maxillary second premolar; MB, DB and palatal (Fig.14).

Bucco-lingual section: Similar to maxillary first premolar. If single canal is present, it is large and centered inside the root.

Mesio-distal section: Narrow resembling maxillary first premolar.

Cross Section:

Cervical: one canal: oval

Two canals: ribbon or figure 8

Mid root: one canal: ovoid

Two canals: round

Apical: round

Outline form: Oval buccolingual in the center of the occlusal surface.

Fig. 14. Maxillary left second premolar with a buccal and palatal roots; the buccal root has two canals while the palatal root has one canal.

Mandibular First Premolar: Fig. (15)

Average Length: 22mm

Roots Number and Form: One root. A relatively bulky crown in relation to the more slender root. Rarely two roots can exist: buccal and lingual.

Canal Type: If one root:

Type I most frequent 75%

Type II or III or IV less frequent

If two roots:

One canal is present in each root (type I).

Bucco-lingual section: Wide, with prominent buccal pulp horn. In young teeth, a small lingual pulp horn is present which may disappear by age giving the pulp chamber the appearance of mandibular canine.

The crown shows a lingual inclination of 30° to the long axis of the root.

Mesio-distal section: Narrow simulating mandibular canine.

Cross Section:

Cervical: Ovoid

Mid root: Ovoid

Apical: Round

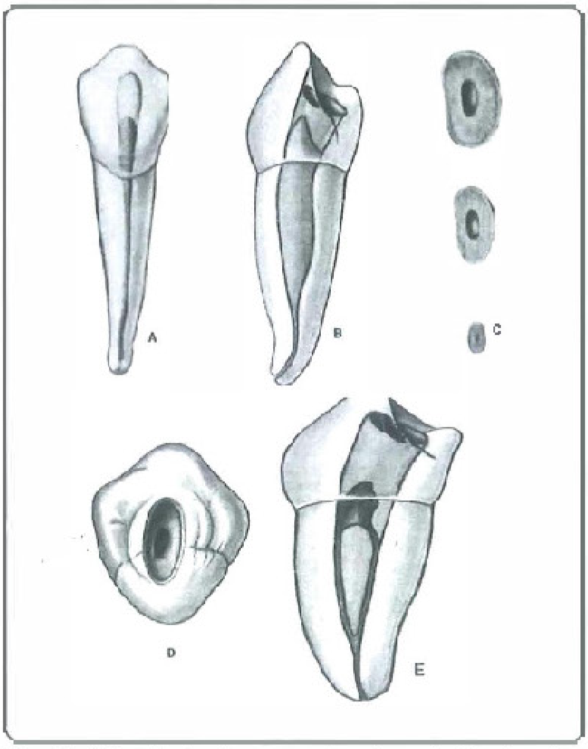


Fig. 15. Mandibular first premolar; A: mesiodistal section, B: buccolingual section (type I), C: cross sections (cervical, middle, apical), D: outline form, E: buccolingual section (type II).

Outline form: Ovoid buccolingually. The access cavity is located in the occlusal surface slightly towards the buccal cusp.

Mandibular Second Premolar: Fig. (16)

Average Length: 21.5mm

Roots Number and Form: One root. Two roots can occur rarely; buccal and lingual. Three roots occur extremely rarely; two buccal and one lingual

Canal Type:

One root: Type I most frequent(85%)

Type II, III, IV less frequent (15%)

More than one root: Type I

Bucco lingual section: Similar to mandibular first premolar except that the lingual pulp horn is more prominent under a well developed lingual cusp.

Mesio-distal section: Similar to mandibular first premolar

Cross Section:

Cervical: ovoid

Mid-root: ovoid

Apical: round

Outline form: Ovoid buccolingually in the center of the occlusal surface.

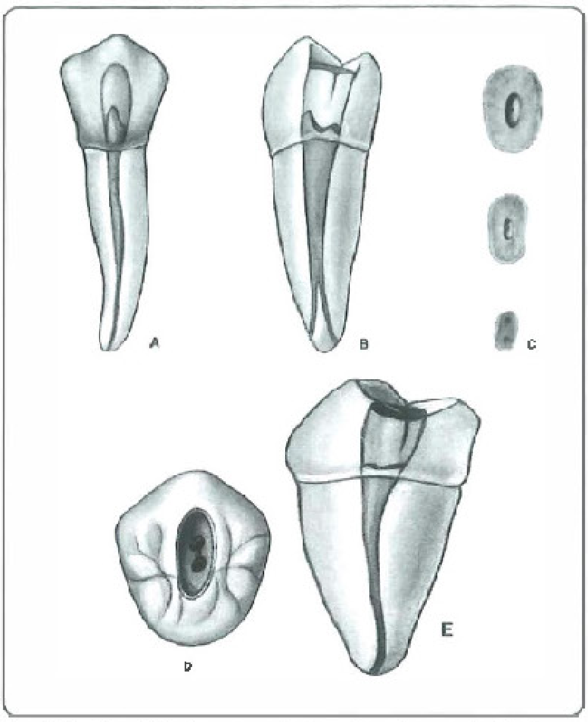


Fig. 16. Mandibular second premolar; A: mesiodistal section, B: buccolingual section (type IV), C: cross sections (cervical, middle, apical), D: outline form, E: buccolingual section (type I).

PULP SPACE MORPHOLOGY OF MOLARS

Maxillary First Molar: Fig. (17)

Average Length: 20.5mm

Roots Number and Form:

Three roots, two buccal and one palatal.

Mesiobuccal (MB): it initially curves to the mesial and near the mid-root region, it curves to the distal.

Distobuccal (DB): has a less curvature to the mesial than MB root forming together a 'cow horn appearance'.

Palatal: (P): The broadest root. Diverges palataly and might have an apical buccal curvature.

Canal Type:

MB root: Type II, III most frequent (over 90%)

Type I least frequent

DB root: Type I, narrow

P root: Type I, wide and broad

Rarely, P and DB roots might have two root canals each.

Root canals follow the direction and the curvature of their roots.

Bucco--lingual section:

The floor of the pulp chamber is in the cervical one third of the root, while the roof is in the cervical one third of the crown. Pulp horns extend under each cusp. Palatal canal is wide and may have a buccal curvature.

Mesio-distal section:

Buccal canals are narrow and well centered in respective roots, but with both orifices located in the mesial 3/5 of the crown.

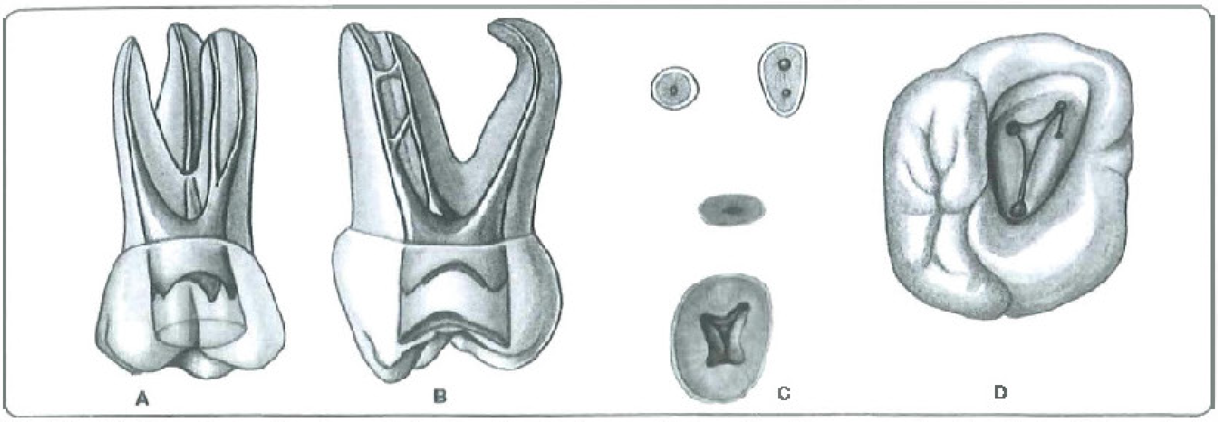


Fig. 17. Maxillary first molar; A: mesiodistal section, B: buccopalatal section, C: cross sections (cervical, middle, apical), D: outline form

Cross Section:

Cevical: triangular or quadrilateral according to the number of orifices at each corner.

MB: ribbon shaped or two separate canals.

DB: small and round

P: wide and oval in a mesio-distal direction.

Mid-root: ovoid or almost round "each canal"

Apical: round

Outline form:

Triangular outline form, with base towards the buccal and the apex towards the lingual, reflecting the anatomy of the pulp chamber. Orifices are positioned at the angles of the triangle. The orifice of the MB canal is usually located under the MB cusp tip, the DB orifice is 2 mm distal and palatal to the MB orifice, while the P orifice is usually found on the same straight line palatal to the DB orifice.

In case of a fourth canal detected, second mesiobuccal canal (MB2), the outline form would be a quadrilateral where the extra orifice is detected in a groove palatal to the mesiobuccal canal (MB1) as a tail of a coma.

The cavity is entirely within the mesial half of the tooth and should be extended enough to allow positioning of the instruments and obturation techniques.

Maxillary Second Molar: Fig. (18)

Average Length: 20 mm

Roots Number and Form:

Three roots, two buccal and one palatal (90%).

Two roots, one buccal and one palatal (10%). One root, extremely rare.

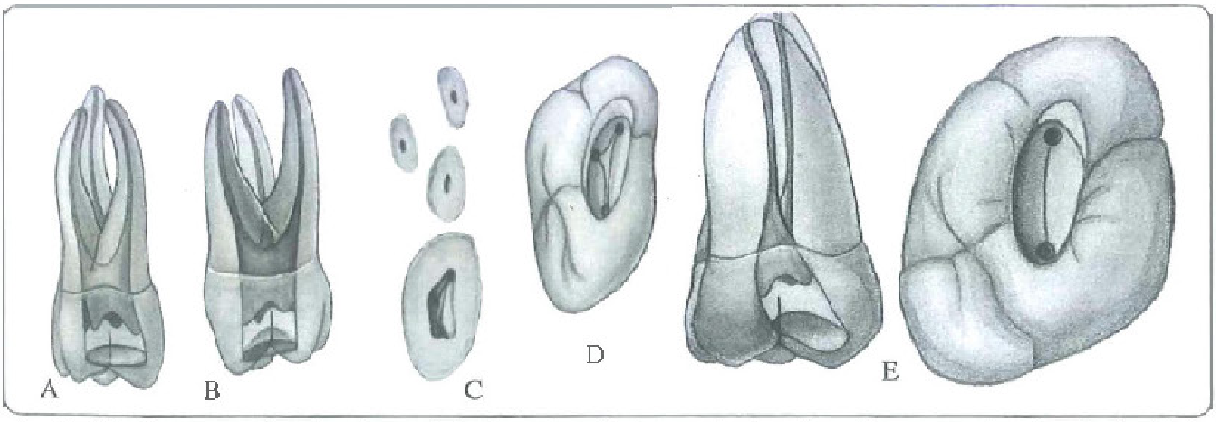


Fig. 18. Maxillary second molar; A: mesiodistal section, B: buccopalatal section, C: cross sections (cervical, middle, apical), D: outline form (three canals), E: rarely, two roots with two canals resulting in an oval outline form.

Canal Type:

Three roots:

MB: Types I, II,or III

P & DB root: Type I each.

Two roots: Each would have canal type I most frequently. The buccal root may have type II or III as well.

One root: may include one, two or three canals.

Bucco--lingual section:

Similar to maxillary first molar.

Mesio-distal section:

Similar to maxillary first molar.

Cross Section:

Cervical: Similar to maxillary first molar, but the DB orifice may be located at the center of the cavity floor and canals are closer M D due to the crowns being narrower M-D than in maxillary first molars.

Mid-root: ovoid or almost round "each canal"

Apical: round

Outline form:

Triangular outline form similar to maxillary first molar, but narrower M-D due to the position of the orifice of the DB canal near the center of the cavity floor.

Mandibular First Molar: Fig. (19)

Average Length: 21mm

Roots Number and Form: Two roots, one mesial and one distal.

Mesial root usually curves distally, broad B-L and narrow M D.

Distal root is either straight or with slight mesial curvature. It is narrower than the mesial root B-L, but wider M-D.

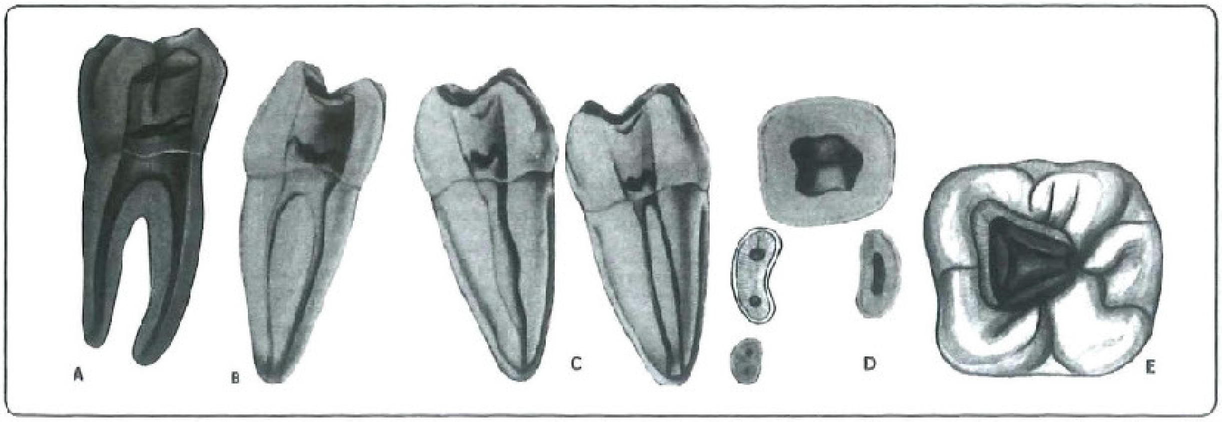


Fig. 19. Mandibular first molar; A: mesiodistal section, B: buccolingual section (mesial view), C: buccolingual section (distal views; typeI/typeIII), D: cross sections (cervical, middle, apical), E: outline form

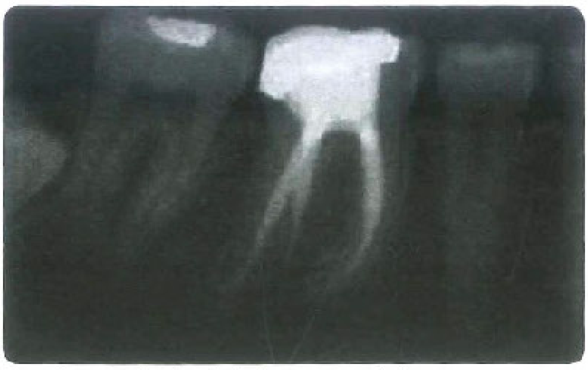


Fig. 20. Mandibular right first molar with 3 roots- M, D and DL and 4 canal systems.

Anatomical studies of over 10,000 teeth found that the three-rooted variety, with a bifurcated mesial or distal root or an additional supplementary root, had a high incidence of 14.6% (Fig. 20).

Canal Type:

Mesial root: always has two canals (MB & ML)

Type III	90%
Type II	10%

The incidence of a Middle Mesial canal (MM) ranges from 1% to 15%. (Fig. 21)

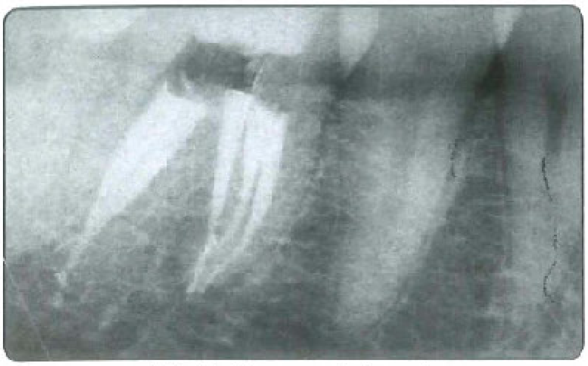


Fig. 21. Three mesial canals

Distal root:	Type I	68.3%
	Type II, III	31.7% (DB&DL)

Root canals follow the direction and curvature of their roots.

Bucco-lingual section: The pulp chamber is in the center of the crown.

Mesial canals are narrow, while the distal canal, if one, is wide and ribbon shaped.

Mesio-distal section:

The pulp chamber is broader M-D than B-L.

The orifices of the mesial and distal canals lie in the mesial 2/3 of the crown. The canals are centered in their roots.

Cross Section:

Cevical: triangular or quadrilateral according to the number of orifices at each corner.

Distal canal is wide, kidney shaped or ribbon shaped.

Mid-root: ovoid or almost round "each canal"

Apical: round

Outline form:

Triangular outline form, with base towards the mesial and the apex towards the distal, reflecting the anatomy of the pulp chamber. Orifices are positioned at the angles of the triangle. The orifice of the MB canal is usually located under the MB cusp tip, the ML orifice is 2 mm lingual to the MB orifice, while the D orifice is usually located 1 mm distal to the central fossa.

In case of a fourth canal detected, DB or DL, the outline form would be a quadrilateral.

The cavity is entirely within the mesial 2/3 of the tooth and should be extended enough to allow positioning of the instruments and obturation techniques.

Mandibular Second Molar: Fig. (22)

Average Length: 20 mm

Roots Number and Form: It may have:

Two roots, 76% of the cases; one mesial and one distal.

One root / root fusion , 21.8% of the studied cases

Three roots; two mesial and one distal

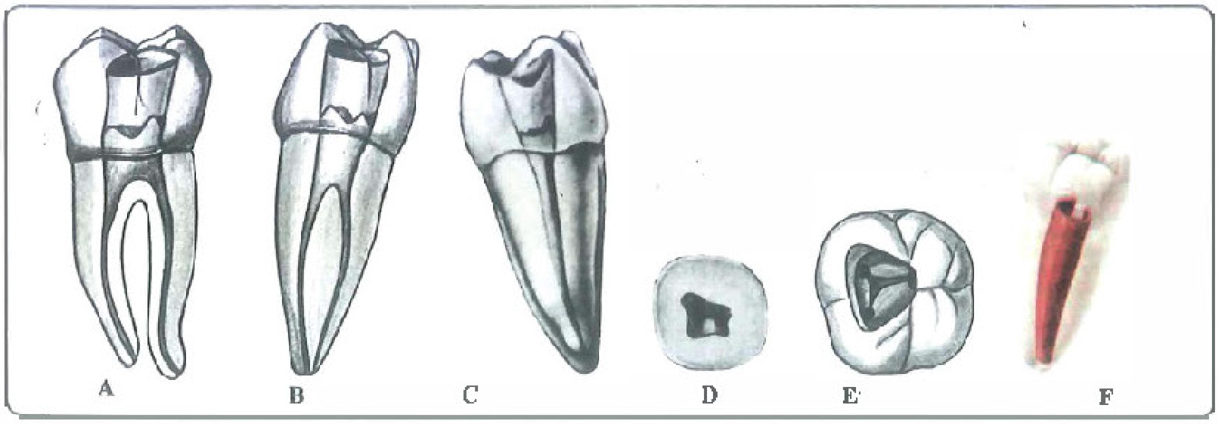


Fig. 22. Mandibular second molar; A: mesiodistal section, B: buccolingual section (mesial views; type III), C: buccolingual section (distal view), D: cross section (cervical), E: outline form, F: C-shaped canal

Canal Type:

If two roots:

Mesial root:

Two canals, Type II or III most frequently

Type I least frequent

Distal root: Type I most frequently

If one root:

Two canals, mesial and distal (type III or II) or one large canal (type I) or ,three canals, or C shaped canal as frequent as 8.5% (Fig. 23).

Most C-shaped canals occur in the mandibular second molar, but they also have been reported in the mandibular first molar, the maxillary first and second molars, and the mandibular first premolar. The pulp chamber of a molar with a C-shaped root canal system is a single, ribbon-shaped orifice with an arc of 180 degrees or more. Below the orifice, the root structure can show a wide range of anatomic variations that would render cleaning, shaping and obturation difficult.

The "C" shape canal configuration can vary along the root depth so that the appearance of the orifices may not be good predictors of the actual canal anatomy. C-shaped canal configuration was classified by Fan et al in 2004 (Fig. 24) as follows :

Category I (C1): The shape is an uninterrupted "C" with no separation or division

Category II (C2): The canal shape resembles a semicolon resulting from a discontinuation of the "C" outline

Category III (C3): Two or three separate canals

Category IV (C4): Only one round or oval canal is in the cross-section

Category V (C5): No canal lumen can be observed (is usually seen near the apex only)

Bucco-lingual section: Similar to mandibular first molar.

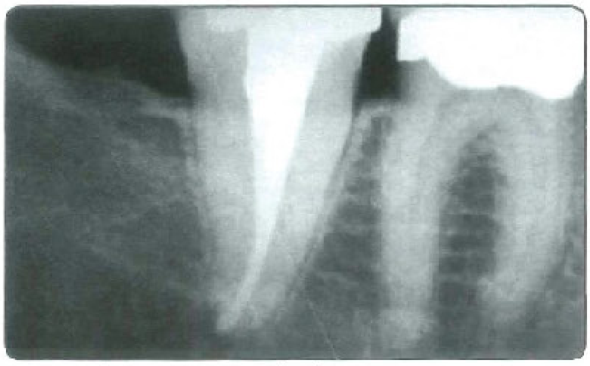


Fig. 23. Anastomosis of all canals into one

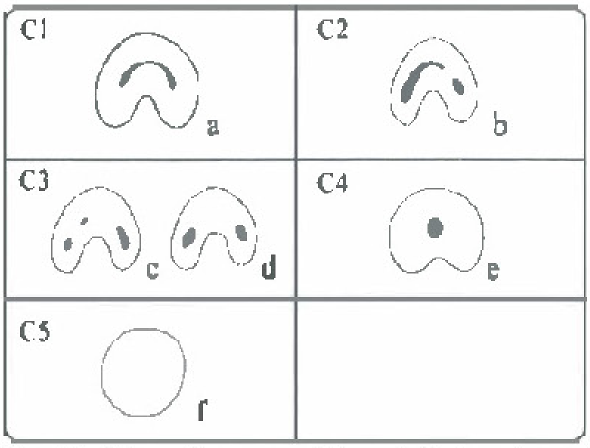


Fig. 24. Schematic representation of C-shaped canal configuration classification described by Fan et al

Mesio-distal section: Similar to mandibular first molar.

Cross Section: Similar to mandibular first molar.

Outline form: Triangular outline form with base towards the mesial and the apex towards the distal, reflecting the anatomy of the pulp chamber. Orifices are positioned at the angles of the triangle.

Coronal Access Cavity Preparation

The endodontic cavity preparation has been divided into coronal and radicular cavity preparations. The principles of cavity preparation established by G.V.Black have been modified by John Ingle to suite the endodontic cavity preparation. It has been divided into coronal and radicular cavity preparation.In this chapter only the coronal cavity preparation will be dealt with.

Principles of coronal access cavity preparation:

I- Outline form

II- Convenience form

III- Removal of remaining carious dentin and defective restorations

IV- Toilet of the cavity

I- Outline form:

The external outline form evolves from the internal anatomy of the pulp chamber. That is to say, the external outline form is established by mechanically projecting the internal anatomy of the pulp onto the external surface. This can be accomplished by drilling into the open space of the pulp chamber and then working with the bur from inside of the tooth to the outside, cutting away the dentin of the pulpal roof as well as the overhanging walls.

To achieve proper outline form, three factors must be considered:

1- The size of the pulp chamber

2- The shape of the pulp chamber

3- The number, position and curvature of individual root canal

1- The size of the pulp chamber:

Larger pulp chambers require larger outline forms than smaller pulp chambers. Since the size of the pulp chamber is usually affected by age, younger patients require more extensive outline forms than older patients where pulp recedes. Trauma, extensive caries as well as medications such as calcium hydroxide are other factors that could affect size of pulp chamber Fig. (25).

2- The shape of the pulp chamber:

The finished outline form should accurately reflect the shape of the pulp chamber. For example, the oval shape of the pulp chamber of maxillary first premolar extend up the walls of the cavity on the occlusal surface, hence revealing the final outline form to be oval as seen in Fig. (26).

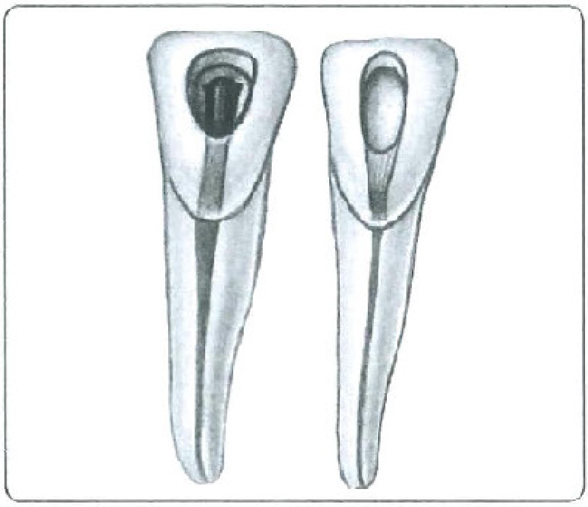


Fig. 25. Effect of age on the size of pulp chamber

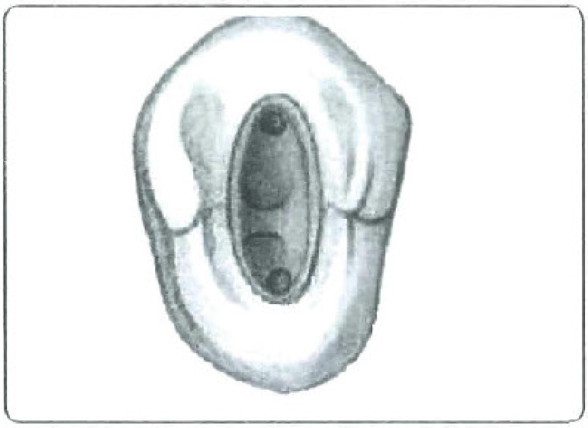


Fig. 26. The outline form reflects the shape of pulp chamber

3 The number, position and curvature of individual root canal:

The access cavity walls should be extended enough to expose orifices of all canals present Fig. (27) as well as facilitate entrance of the instrument into each root canal without interference and allow instrument approach to the apical foramen without strain. Hence, the convenience form partially regulates the ultimate outline form Fig. (28).

II- Convenience form:

It is the form given to the access cavity to improve visibility, instrumentation and obturation of the root canal by providing a straight line access (SLA) from the occlusal surface to the apical foramen. Four important benefits are achieved through the convenience form.

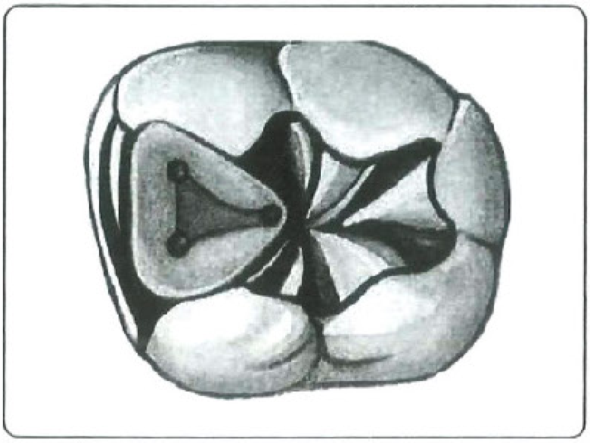


Fig. 27 Shape of pulp chamber is affected by number of root canals

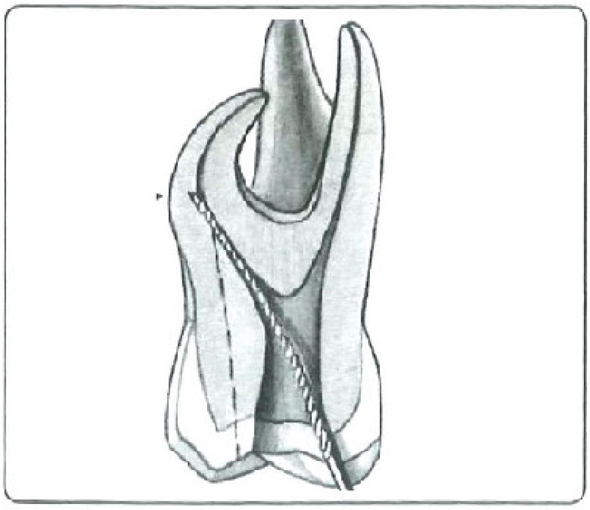


Fig. 28. Dentin interference should be removed to allow proper preparation of curved canals

1- Unobstructed access to the canal orifice:

Enough structure must be removed to allow instruments to be easily inserted into the orifices of each canal without interference from the overhanging walls. In some cases the outline form could be modified to facilitate search for additional canals as lower incisors, premolars, maxillary first molars and mandibular molars.

2- Direct access to the apical foramen:

Enough structure must be removed to allow freedom of the instruments within the coronal cavity allowing them to extend down into the canal in an unstrained position Fig. (29). This is especially true in severely curved canals. Occasionally total decuspation could be required.

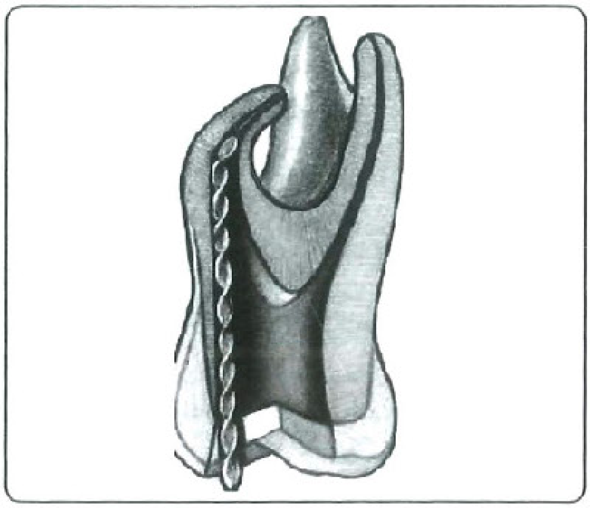


Fig. 29. Endodontic instruments should extend into the apical third without any strain

3- Complete authority over the enlarging instrument:

If the instrument is impinged at the canal orifice by tooth structure that should have been removed, the clinician will lose control of the direction of the tip of the instrument that will be directed instead by the intervening tooth structure. On the other hand, removal of enough tooth structure around the orifice allows the instrument to be controlled by two factors only; the clinician's fingers holding the handle of the instrument and the canal walls touching the tip of the instrument. Failure to properly modify the access cavity outline will ultimately lead to failure as ledge, root perforation, instrument fracture, improper cleaning and shaping.

4- Extension to accommodate filling technique:

Enough structure must be removed to facilitate the use of obturating instruments as well as the application of various obturation techniques (e.g. softened gutta-percha technique) and the sophisticated use of endodontic implants.

III- Removal of remaining carious dentin and defective restorations:

Carious structure and defective restorations must be removed to prevent obstruction of the orifices by loose pieces of restoration, to reduce mechanically the bacterial population, to eliminate discolored tooth structure as well as

to reduce the possibility of bacteria laden saliva leaking into the prepared cavity.

IV- Toilet of the cavity:

All caries, calcified debris and necrotic material should be removed by irrigation from the pulp chamber before radicular preparation is begun to avoid obstruction of the root canals by metallic or calcified debris or increasing bacterial population by infected soft debris.

The use of round burs and long blade endodontic spoon excavators Fig. (30) as well as the irrigation with sodium hypochlorite are excellent measures for cleansing the chamber. The chamber is finally wiped out with cotton. Air blasts must never be aimed down the canals to avoid emphysema of oral tissues.

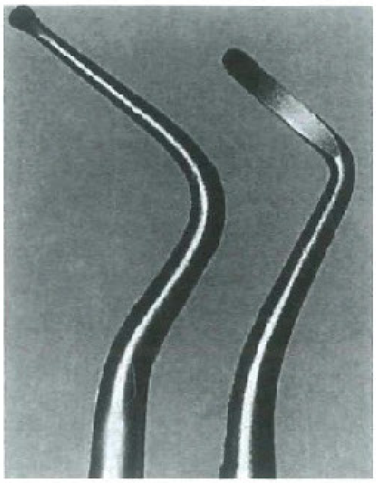


Fig. 30. Endodontic spoon excavators

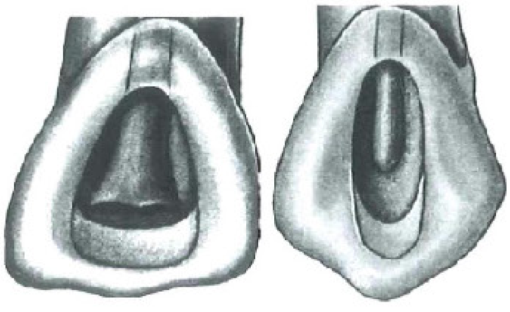


Fig 31 & 32. Outline forms of maxillary incisor and canine

Endodontic coronal access cavity preparation in maxillary and mandibular anterior teeth:

The endodontic access preparation is always performed in the centre of the lingual/palatal surface of all the anterior teeth. For the incisors, the outline form of the cavity is triangular in shape with its base towards the incisal edge and its apex towards the cingulum Fig. (31). For the canines, the outline form is oval in shape in an inciso-gingival direction Fig. (32). The cavity extends between the two marginal ridges.

The lingual/palatal surface is divided into thirds and the initial penetration is carried out in the center of the middle middle third just above the cingulum Fig. (33A) using a round carbide bur #2 at right angle to the long axis of the tooth. After the enamel is penetrated and dentin is reached, the bur is directed 45° to the long axis of the tooth. A surgical length round bur could be used to penetrate the pulp chamber Fig. (33 B). The operator should have the sensation of drop ping into an empty space.

Deroofing i.e. complete removal of the roof of the pulp chamber is then carried out using a round bur #3 or a tapered stone with round end or EndoZ bur. The instrument is held parallel to the long axis of the tooth while cutting on withdrawal i.e. working from inside the chamber to the outside without applying any pressure Fig. (33C).

The cavity is then irrigated with sodium hypochlorite 2.5% to flush away the debris. The endodontic explorer can be used to detect any overhanging walls that should be then removed till the explorer can be freely placed into the canal. A lingual projection of dentin (lingual shoulder) corresponding to the lingual cingulum is a common feature in anterior teeth and care should be taken as to its removal using a tapered diamond stone on withdrawal Fig. (33D). This would provide a smooth transition between the pulp chamber and the canal. Sometimes a small round bur can be used to remove pulp horn debris Fig. (33E).

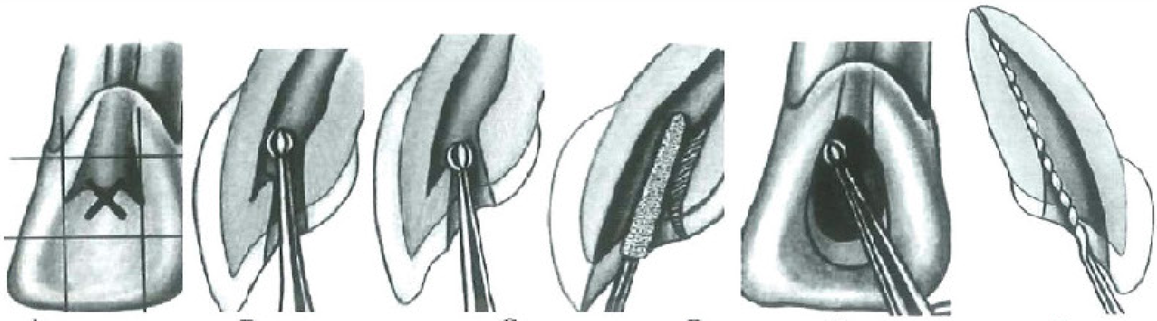


Fig. 33. Steps of endodontic coronal cavity preparation in anterior teeth

Flaring, smoothening and finishing of the cavity dentinal walls and margins are best achieved using a long tapered diamond stone to facilitate insertion of instruments freely into the canal without any strain Fig. (33F).

Errors during endodontic cavity preparation in maxillary and mandibular anteriors

The following errors could occur during access preparation in anterior teeth Fig. (34):

1- Gouging of labial wall due to failure to notice the lingual axial inclination of anterior teeth.

2 Gouging of distal wall due to failure to notice the mesial axial inclination of anterior teeth.

3- Labiocervical perforation due to lack of convenience extension incisally.

4- Ledge due to underextension and incomplete authority over the instruments due to insufficient convenience extension.

5- Missed canal due to insufficient convenience extension.

6- Discoloration caused by failure to completely remove pulp debris and necrotic tissue due to incisal uderextension of the cavity.

Endodontic coronal access cavity preparation in maxillary and mandibular premolar teeth

The endodontic access preparation is always performed on the occlusal surface of premolar teeth. For the maxillary premolars, the outline form of the cavity is oval in shape with the larger dimension in the bucco-lingual direction Fig. (35). For the mandibular premolars, the outline form is ovoid bucco lingually if the canal is centrally located and further extension bucco-lingually could be needed if an additional canal is detected Fig. (36).

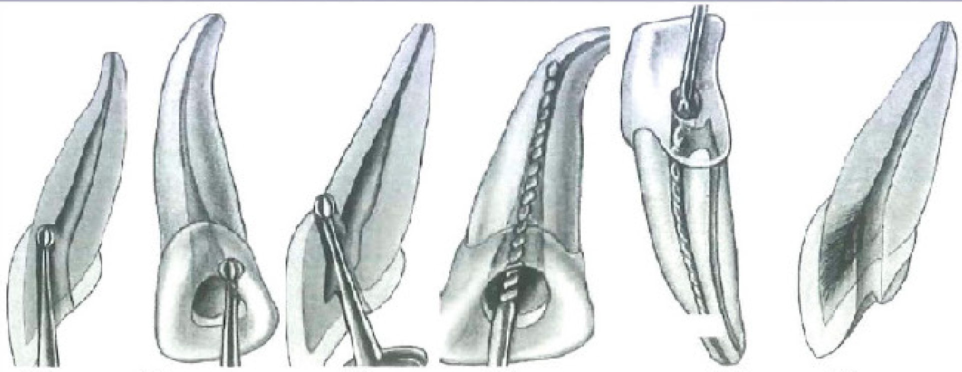


Fig. 34. Errors during endodontic coronal cavity preparation of anterior teeth

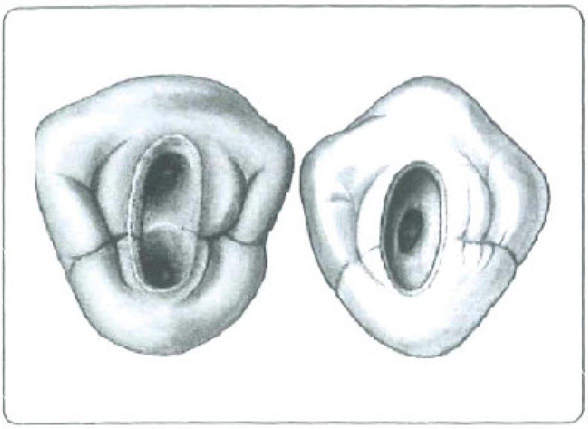


Fig 35 & 36. Outline forms of maxillary and mandibular premolar teeth

The initial penetration is carried out through the occlusal surface in the center of the central groove Fig. (37A). A regular length round bur is aligned parallel to the long axis of the tooth Fig. (37B). On reaching the pulp chamber, the operator will experience the sensation of dropping into an empty space.

Deroofing and extending the cavity bucco-lingually is then carried out using a round bur #3 or a tapered stone with round end or EndoZ non cutting tip bur. The instrument is held parallel to the long axis of the tooth while cutting on withdrawal i.e. working from inside the chamber to the outside without applying any pressure Fig. (37C). Care should be given as to keep the mesio-distal dimension narrow to avoid perforation since premolars are narrow mesio-distally in the cervical region.

The cavity is then irrigated with sodium hypochlorite 2.5% to flush away the debris and an endodontic explorer is used to locate the orifices Fig. (37D) such that the buccal orifice is usually detected under the buccal cusp tip, while the palatal orifice is usually located at the base of the palatal cusp. The access cavity should be modified if needed to allow free insertion of the explorer into the orifices.

Flaring, smoothening and finishing of the cavity dentinal walls and margins are best achieved using a tapered diamond stone or EndoZ bur Fig. (37 E&F).

Errors during endodontic cavity preparation in maxillary and mandibular premolars Fig. (38)

1- Perforation at the mesio-cervical region due to failure to recognize the distal axial inclination of the tooth.
2- Underextended preparation exposing only the pulp horns due to lack of knowledge about the position of floor of pulp chamber. The light color of dentin is a clue to a shallow cavity.
3 Overextended preparation could be due to searching for canal orifices and failure to recognize the recessed pulp in preoperative radiograph.
4- Failure to explore, and obturate a second canal due to under extended cavity or lack of knowledge of the anatomy.
5- Fractured instrument as a result of loss of instrument control due to lack of sufficient convenience extension.

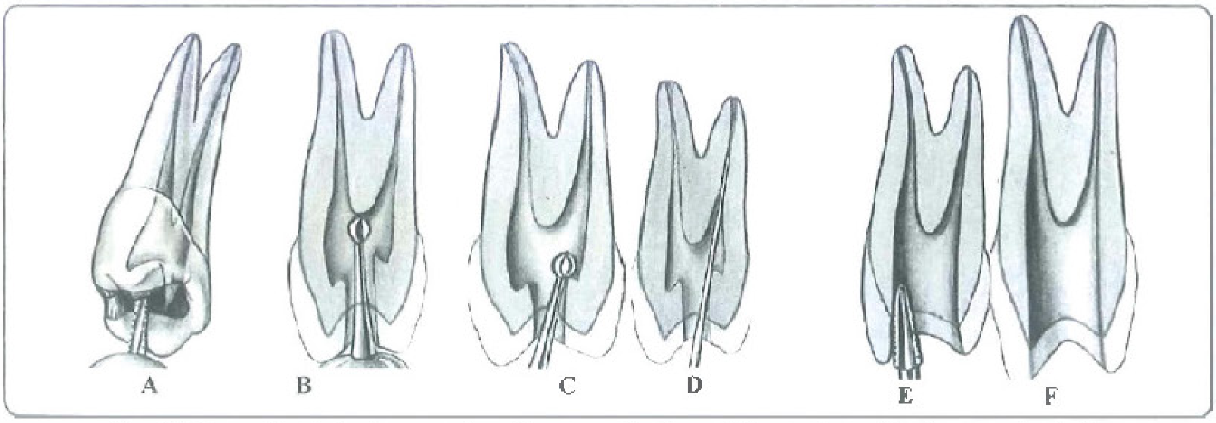


Fig. 37. Steps of endodontic coronal cavity preparation in maxillary and mandibular premolar teeth

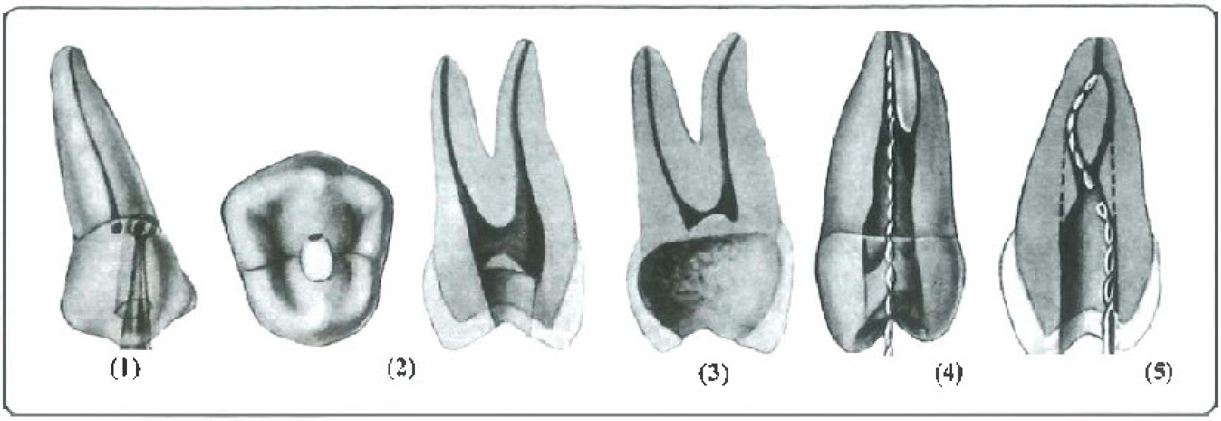


Fig. 38. Errors during endodontic coronal cavity preparation of premolar teeth

Endodontic coronal access cavity preparation in maxillary molar teeth

The access preparation is always on the occlusal surface. The outline form is triangular in shape with its base towards the buccal surface and its apex towards the palatal with three orifices at the corners. If an extra fourth canal is detected, the outline form would be quadrilateral. The entire preparation is located within the mesial half of the tooth without or slightly crossing the oblique ridge. Initial penetration is carried out in the exact center of the mesial pit, midway between the mesial ridge and the oblique ridge, using round bur #3 Fig. (39A&39B). The bur is slightly directed towards the palatal where the orifice of the largest canal exists. Once the pulp chamber is penetrated, the operator will experience the sensation of dropping into an empty space. An endodontic explorer is used to locate the orifices Fig. (39C). Complete deroofing is carried out using round bur or Endo Z or tapered stone with round end working from inside out, parallel with the long axis and applying no pressure Fig. (39D).

The pulp chamber is irrigated and dried. The MB canal orifice should be detected beneath the MB cusp tip. The DB canal orifice is located 2-3 mm to the distal and slightly palatal to the MB orifice. The palatal canal orifice is located beneath the base of MP cusp. An extra canal orifice (MB2/MP) could be detected mesial and palatal to the original MB orifice and would appear as a tail of a comma.

Planing, flaring and smoothening of the cavity walls should be then achieved using tapered stone with round end/ Endo Z Fig. (39E&39F).

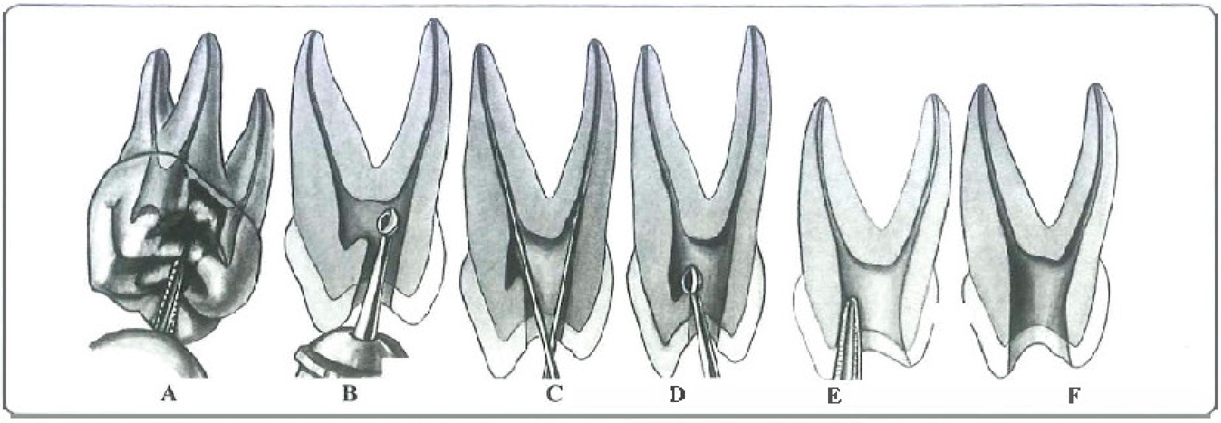


Fig. 39. Steps of endodontic coronal cavity preparation in maxillary molarteeth

Endodontic coronal access cavity preparation in mandibular molar teeth

The access preparation is always on the occlusal surface. The outline form is triangular in shape with its base towards the mesial surface and its apex towards the distal with the three orifices at the corners. If an extra fourth canal is detected, the outline form would be quadrilateral. The entire preparation is located within the mesial two-thirds of the tooth. Initial penetration is carried out in the central pit using round bur #3 Fig. (40A). The bur is slightly directed towards the distal where the orifice of the largest canal exists. Once the pulp chamber is penetrated, the operator will experience the sensation of dropping into an empty space. The pulp chamber is irrigated and dried. An endodontic explorer is used to locate the orifices Fig. (40B). Complete deroofing is carried out using round bur or Endo Z or tapered stone with round end Fig. (40C) working from inside out, parallel with the long axis and applying no pressure.

The MB canal orifice could be found beneath the MB cusp tip. The ML canal orifice is located 2-3 mm lingual to the MB orifice. The distal canal orifice is located 1 mm distal to the central fossa. An extra canal orifice could be detected lingual or buccal to the distal orifice to end up with two distal canals; DB and DL.

Planing, flaring and smoothening of the cavity walls should be then achieved using tapered stone with round end/ EndoZ (Fig 40. D&E).

Errors during endodontic cavity preparation in maxillary and mandibular molars

A- Underextended preparation where only pulp horns have been exposed. The entire pulpal roof is unremoved due to lack of knowledge of difference between floor of pulp chamber and the dentinal roof with its lighter colour indicating a shallow cavity.

B- Furcal perforation due to failure to notice the narrow pulp chamber or applying pressure during deroofing.

C- Overextended preparation and gouging of the crown due to failure to observe pulp recession in pre-opertaive radiograph.

D- Perforation at the mesio-cervical region in lower molars caused by failure to orient the bur parallel with the long axis.

E- Missed canal due to underextended endodontic cavity preparation leaving part of pulpal roof unremoved.

F- Ledge due to underextended cavity.

Axioms of Pulp Anatomy (Fig 41)

The following axioms of pulp anatomy can be of great help:

1- The two orifices of the *maxillary first premolar* are further to the buccal and to the lingual than usually suspected.

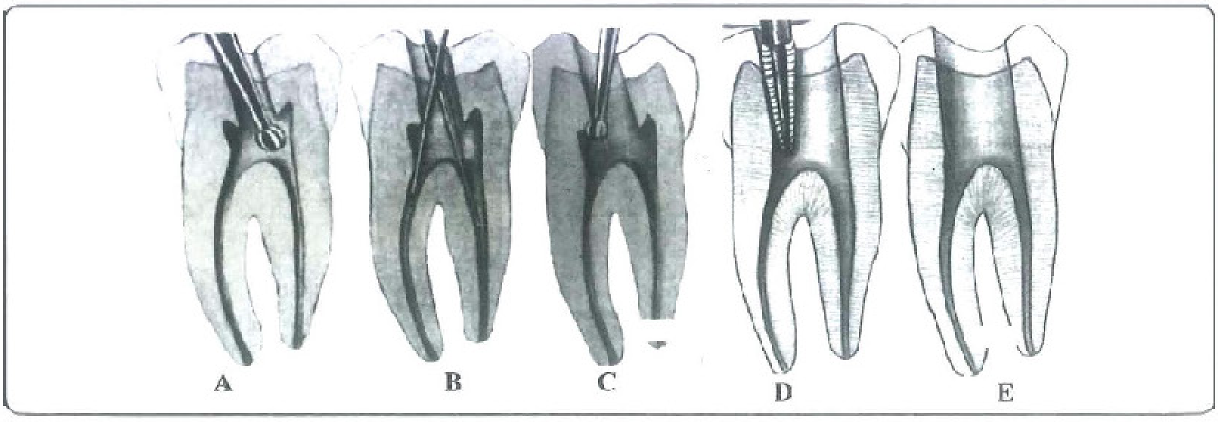


Fig. 40. Steps of endodontic coronal cavity preparation in mandibular molar teeth

2- The orifices of the mesio-buccal canals in *molars* are well up under the mesio-buccal cusps and the outline form should be widely extended into the cusp.

3- The orifice of the palatal canal in *maxillary molars* is not too far to the lingual, but is actually in the center of the mesial half of the tooth.

4- The orifice of the disto-buccal canal in *maxillary molars* is not too far to the disto-buccal, but is almost buccal to the palatal orifice.

5 The orifice of the distal canal in *mandibualr molars* is not too far to the distal, but is actually in the exact center of the tooth.

6- The orifice of the mesio-lingual canal in *mandibualr molars* is not too far to the mesio-lingual, but is almost mesial to the distal orifice.

7- Certain anatomic variations occur with enough frequency to warrant mention:

a- The mesio-buccal root of maxillary first molar may have an extra mesio-buccal canal (MB2/ mesiopalatal) just palatal to the mesio-buccal orifice. It is located in the groove that comes off the mesio buccal orifice like the tail on a comma and should be detected.

b- Mandibular first molar may have two distal canals with either separate orifices or one common orifice.

c- Mandibular first premolars frequently have a second canal branching off the main canal to the buccal or lingual, several millimeters below the pulp chamber floor.

d- Mandibular incisors frequently have two canals. The lingual canal is usually hidden beneath the internal lingual shoulder that corresponds to the cingulum. This dentin prominence must be removed as previously mentioned to permit proper exploration.

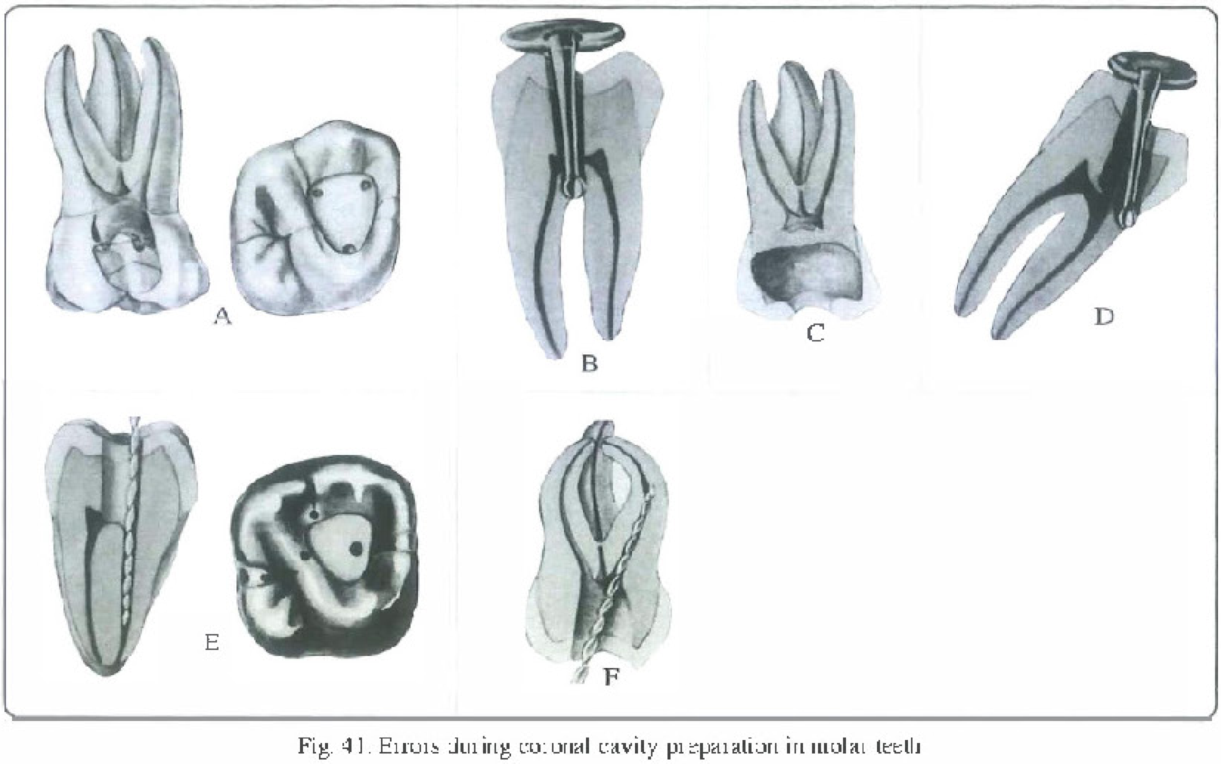


Fig. 41. Errors during coronal cavity preparation in molar teeth

Chapter review Questions

1. Describe access cavity preparation for anterior teeth.
2. Describe access cavity preparation for premolars.
3. Describe access cavity preparation for molars.
4. Mention various errors in access cavity preparation and their causes.
5. Describe morphological features for anterior teeth and mention their most common variations.
6. Describe morphological features for premolars and mention their most common variations.
7. Describe morphological features for molars and mention their most common variations
8. Discuss principles for access cavity preparation and factors affecting each.

References

- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Walton RE, Torabinejad M. Principles and Practice of Endodontics. 4th ed. W.B. Saunders Company. 2009.
- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics . 4th ed. Williams and wilkins,1994.
- Vertucci FJ, Seelig A, Gillis R: Root canal morphology of the human maxillary second premolar, Oral Surg Oral Med Oral Pathol 38:456, 1974
- Fernandes M, de Ataide I, Wagle R. C-shaped root canal configuration: A review of literature. J Conserv Dent 2014;17 312-9
- Adams N, Tomson PL. Access cavity preparation. Br Dent J. 2014 Mar;216(6):333-9.

12

Root Canal Instruments

Ghada El Hilaly Eid

Intended Learning objectives

After reading this chapter, the student should be able to

1. Describe the design (longitudinal, cross sections, tip configuration) of basic stainless steel root canal instruments, their mechanical properties and their mode of action.
2. Explain the basis for sizing and taper (standardization) of k type and H type hand instruments.
3. Differentiate between conventional stainless steel files and those of alternative designs and material of construction.
4. Explain factors affecting fracture of rotary nickel titanium instruments and the technique for prevention of instrument separation during use.
5. Describe new innovations in Nickel Titanium instruments design, kinematics to improve its efficiency and reduce procedural mishapes

Chapter Outline

CLASSIFICATION OF INSTRUMENTS AND DEVICES ACCORDING TO SEQUENCE OF USE:

I. Diagnostic instruments:

- Basic examination instruments (mirror, explorer, plier, periodontal probe).
- Specialized devices:
  - Visual aids:Magnifying loups (2-6X), Surgical microscope (2-20X), Transillumination
  - Sensitivity and vitality pulp testing: Thermal sensitivity tests (neural stimulation by cold testing, hot testing), electric pulp sensitivity tester (neural stimulation), Laser doppler flowmetry for vitality testing (records blood flow), Pulp Oximetry for pulp vitality (records oxygen saturation of red blood cells).
  - Radiographs: Plain radiograph, digital radiography (Digora, Radiovisiography RVG), Computed tomography CT and cone beam volumetric tomography CBVT.

II. Instruments used during access preparation: Regular and surgical length round burs, taperd burs with round ends, Endo Z bur (safe end bur to avoid bifurcation perforation)

III. Exploring instruments: Endodontic explorer

IV Extirpating instruments: Barbed broaches

V Root canal enlarging instruments:

- **Basic Manually Operated Stainless Steel instruments:** K type reamer, K type file, H file, and historically R file.
- **Modified Design** stainless steel instruments
- **Engine driven enlarging instruments:** Rotary Nickel Titanium instruments, reciprocating instruments, vibratory instruments.

VI. Obturation materials, instruments and devices:

Materials:

Gutta-percha core filling material and root canal sealers. Resilon/Epiphany obturation system.

Instruments and devices:

- Non softened technique:
  - Spreader: instrument with pointed tips for lateral compaction technique.
- Softened techniques:
  - Plugger: instrument with flat tips for warm vertical compaction technique.
  - Thermal applicator: uses electric devices to warm the instrument tip during compaction such as: Touch "N" heat, Endotec, System B.
  - Thermomechanical compactor: the friction of a mechanically rotating instrument softens the gutta-percha and packs it inside the root canal such as Mc Spadden compactor, Quick- fill, Multiphase II pac Mac-compactor.
  - Injection systems for injecting thermally softened gutta-percha such as Obtura, Ultrafil.
  - Gutta-percha-carrier: uses alpha phase gutta-percha coated on a metal or plastic carrier, that is softened in special oven and inserted inside the canal, such as Thermafil, Successfil, Trifecta.

VII Miscellaneous

- **Apex locators:** Electronic devices used to determine the working length before root canal preparation.
- **Endobox** for organizing the endodontic files.
- **Endometer:** Metal or plastic autoclavable ruler for measurements during root canal enlargement.
- **Rubber dam set for isolation:** Composed of rubber dam sheet, punch, clamps, clamp holder, and frame.

EXPLORING INSTRUMENTS

Endodontic explorer or probe;

It has biangle or contraangle working part, used for exploration of the root canals' orifices. Its working part is long because of the greater distance needed to reach the pulp chamber floor.

EXTIRPATING INSTRUMENTS

Barbed broaches Fig.(1,2).

They were the earliest manualy operated instrument to extirpate vital diseased pulp tissues. Barbed broach is a tapered instrument of soft steel that is notched to produce sharp barbs extending outward from the shaft to snag tissues

Correct use of the barbed broach involves its careful insertion in the canal until dentin walls are felt. It is slightly withdrawn, then rotated a few rotations and removed. Vital tissue become entangled on the barbs and removed before files are placed to the full working length.

If the operator forces the instrument apically, the barbs bend towards the shaft. However, when the instrument is withdrawn, the barbs extend and engage dentin. Further forceful removal may fracture the barbs inside the canal. Barbed broach can also be used to remove paper points or cotton pellets of intertreatment dressings that were accidentally lodged into the canal.

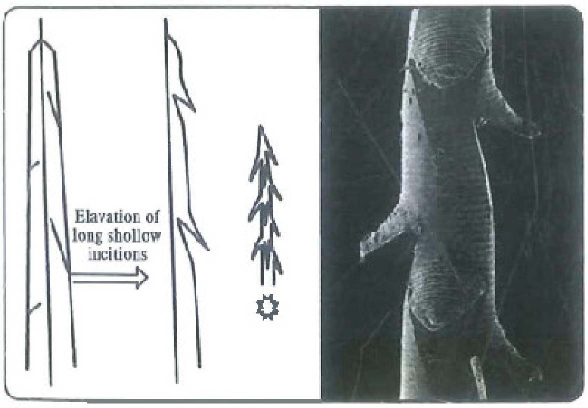


Fig.1. Manufacturing of barbed broach; Elevation of long shallow incisions

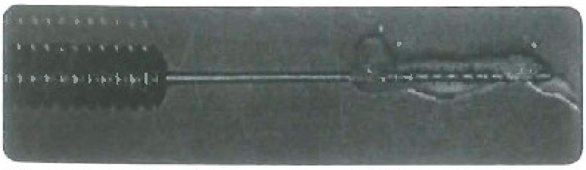


Fig. 2. Barbed broach entangling vital diseased pulp tissue

ROOT CANAL ENLARGING INSTRUMENTS

The realization that the whole pulp cavity had to be cleaned and shaped in order to receive three dimensional fluid tight filling material, allowed various instruments to evolve.

Mode of operation:

Intracanal instruments are divided into:

Manually operated instruments: example barbed broaches (for extirpation only), K Reamers, K files and H-files.

Engine driven instruments that operate by low speed handpiece: where the latch type of attachment is part of the working section. Typical instruments are Gates Glidden Drills (GG) burs & Pesso reamers.

Engine driven instruments similar to hand operated instruments; however the handle is replaced by a latch type of attachment. This include; **First:** Rotary Nickel titanium instruments that operate by special gear reduction- torque control handpieces. **Second:** NiTi instruments that operated by reciprocation or adaptive motion. **Third;** instruments that operates by vibration (Sonic or Ultrasonic).

BASIC MANUALLY OPERATED STAINLESS STEEL INSTRUMENTS

Basic hand enlarging instruments are readily available: *K Reamers, K file, Hedström or H type file* and historically the Rat-tail or Rasp.

Kerr Manufacturing company was the first to produce files in the early 1900s, hence the name K-type fie (K file) and K-type reamer (k reamer).

1- MATERIAL OF FABRICATION:

Initially, root canal instruments were manufactured from *carbon steel*. However, chemicals e.g. chlorine and steam sterilization caused corrosion. Nowadays, carbon steel instruments of small sizes are only used in initial penetration of narrow canals.

The use of *stainless steel* improved the quality of instruments. Recently, *Nickel Titanium* (NiTi) alloy, which is extremely flexible, helps maintaining curved canal shape. NiTi instruments were initially available as manually operated instruments then nowadays they are engine driven.

Benefit of materials that can be precurved:

Instruments manufactured of stainless steel or **heat treated NiTi with stable martensite can be precurved Fig. (3).** Since few canals are perfectly straight, when straight instrument is placed in a narrow curved canal, it may be stopped at the start of canal curvature. If the file is forcibly rotated at this point, it will merely drive the tip of the instrument deeper in dentin and create a ledge. For this reason it is best to enter these canals with instrument that has been precurved. The file will have a better chance to traverse any curvature. Simply mild rotation (clockwise and anticlockwise watch-winding) of the handle will allow the tip to slid off and continue towards apex.

Precurving is either a gradual curve to facilitate insertion in a curved canal or a sharp (30°) curve near the tip (used to bypass a ledge from previous canal preparation). The use of coronal preflaring (by Gates-Glidden drills or increased taper instruments) greatly enhances the ease by which the precurved file may be inserted.

N.B. austenitic NiTi can not be precurved.

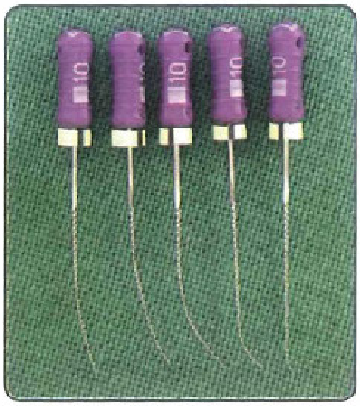


Fig.3. Precurving of stainless steel instruments

2- INSTRUMENT FABRICATION Fig.(4):

Stainless steel K-files and K-reamers were originally manufactured from steel piano wires. For reamers: Three flat surfaces are ground on the sides of a piece of wire, to tapered triangular cross section while for files four surfaces are ground to a square, cross section. Then the wire is counterclockwise twisted by stabilizing it on one end and the distal end is rotated. Thus, spiral cutting edges are produced. Fewer spirals are used for reamers and more spirals for files.

During this process the steel is work hardened which affects instrument's flexibility. Thus, a reamer with fewer spirals is more flexible than a file of similar size because of less work hardening. A pyramidal tip (75±15°) is produced by grinding after twisting.

H-file is manufactured by machining the instrument directly on the lathe.

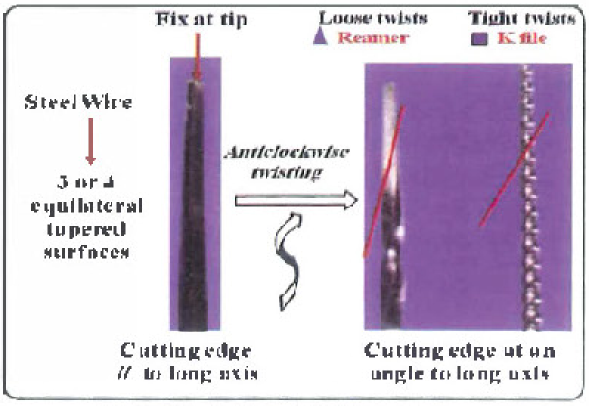


Fig.4. Fabrication of K File and reamer

3- DEFINING INSTRUMENTS BY FUNCTION Fig.(5).:

Each group of instruments has a specific purpose, which normally couldn't be carried out by a different instrument. For example, a reamer is designed to cut a circular hole and can't be used efficiently as a file for oval canals.

K Reamers cut and enlarge canals with rotational motions, (insertion until binding, and clockwise 1/4 to 1/2 turning to engage the blades in dentin, then retraction).

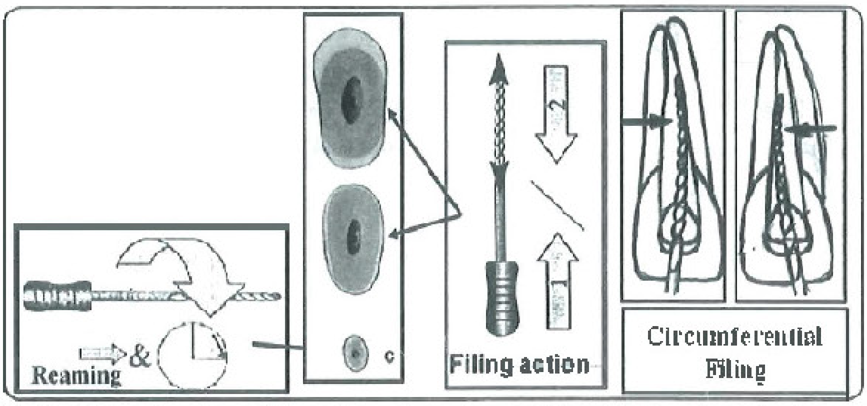


Fig.5. Different modes of file actions along the canal length. Reaming apically and circumferential filing in the coronal 2/3.

K Files are instruments that mainly enlarge canals with a push-pull planning motion; passive insertion until binding and heavier withdrawal dragging against the canal wall.

N.B. *Filing motion* is different than pistoning which involves going up and down forcefully. This tends to pack dentinal filing at the apex and alter canal shape.

N.B. *Circumferential filing* is the method of filing along the circumference of oval canals, whereby the instrument is moved first towards buccal side of the canal, then reinserted and slightly moved mesially. This continues lingually and then distally until all dentin walls have received rasping. Reaming is not suitable in oval canals, larger sizes to include the BL extremities will be on the expense of the MD dentin thickness.

4- DESCRIPTION OF BASIC MANUALLY OPERATED INSTRUMENTS: K REAMER, K FILE, H FILE, R FILE.

K- Reamers, Fig.(6)

They are the original intracanal instruments used since the nineteenth century.

1. They are manufactured by **loose anticlockwise twisting** a tapering length of stainless steel wire which has a **triangular** cross section. Since each angle of the triangle cross section is approximately **60°**, a sharp knife edge is available to shave canal walls.
2. It has few number of spirals/unit length. The number of the flutes ranges from **0.5 to 1 flute / mm.**

   The fewer twists result in increased clearance space (space between the cutting edges), which tends to prevent clogging of the cutting edge (clogged flutes decrease the instrument cutting effectiveness).
3. The instrument has a degree of **flexibility** because the cross sectional area of the triangular bank is not excessively wide. Furthermore, it is less work hardened by having only loose twists.
4. The **tip** is sharp for better penetration of root canal. However, a disadvantage of a sharpened point is that it can lead to a ledge or perforation in curved canals.
5. The **Helical angle** (angle formed between the cutting edge and the long axis of instrument) is approximately 20°. This provides information about the clinically effective cutting motion, whereby *rotational cutting motion* is recommended; **watch winding** as if winding of a watch: (30°-60° clockwise & counterclockwise) or **reaming action** (insertion until binding, and clockwise 1/4 to 1/2 turning to engage the blades in dentin, then retraction). Reaming motion is efficient with cutting edges that more closely parallels the instrument shaft.

6. They are only used in the preparation of the apical round portion of the root canal by clockwise reaming action.

7. Dentists can use reamers to place root canal sealers and intracanal medications. (**N.B**. the reamer is turned counterclockwise to force sealer apically).

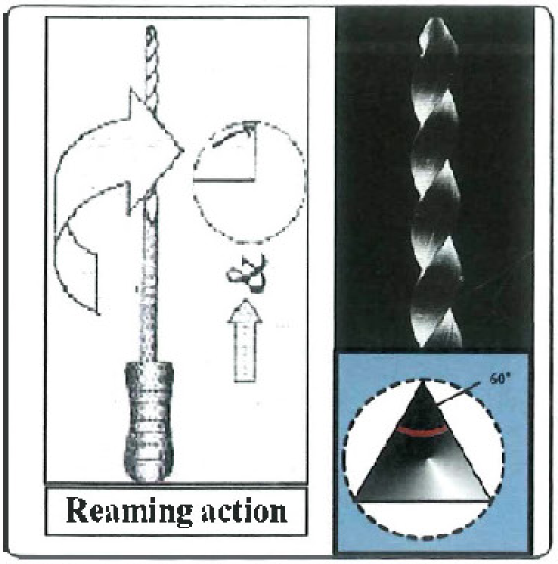


Fig.6. K type reamer; lateral view, cross-sectional view and mode of action

K -File, Fig. (7)

The K file was developed by changing some of the principles of reamer's design to improve instrument efficiency.

1. They are manufactured by **tight anticlockwise twisting** a tapering length of stainless steel wire which has a **square** cross section, thus forming an instrument with cutting edges along the spiral.

2. **Tighter twists** increased the number of the flutes to be in the range from **1.5 to 2.5 flute/mm**.

   The tight twists caused the **clearance space** to be smaller and thus easily clogged with dentin. This requires periodic cleaning of the instrument before reinserting in the canal. Frequent irrigation is needed to remove canal debris and prevent packing of debris apically.

3. The square blank has four angles of 90°. **It is not as sharp** as the triangular blank. This decreased sharpness of the cutting edge is compensated by the more twisting and thus greater number of cutting edges.

4. The larger square cross sectional diameter (compared to the triangular of a reamer) is **less susceptible to breakage**. However, the tighter winding of the file and its greater diameter causes decreased **flexibility**.

5. The **Helical angle** (angle formed between the cutting edge and the long axis of the instrument) is about 40°. This provides information about the effective cutting motion. Both pull push filing and reaming motions are recommended.

6. K file is a **universal** instrument because it can be used as both a file (scraping the flutes against the canal walls) and as a reamer. The push pull filing motion is more efficient where many flutes/mm on the instrument contact the canal walls. **N.B**. The push pull filing motion is most efficient with cutting edges that are nearly at right angle to the instrument shaft.

7. It can be used in preparing the oval middle and coronal parts of the canal by circumferential **filing action** and the round apical part by **reaming action**.

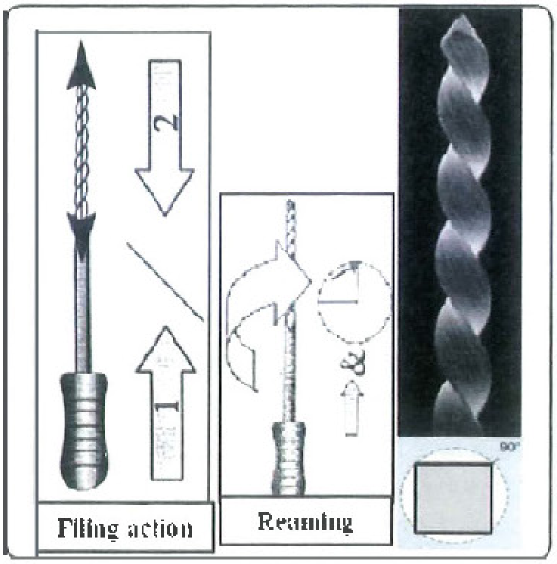


Fig.7. K type file, lateral view, cross-sectional view and the two modes of action (Filing and reaming)

Hedström File or H File, Fig.(8)

1. H-type instrument has spiral edges arranged to allow cutting only during a pulling stroke. It is manufactured by **machining** (lathe-grinding or milling) round stainless steel blanks into a tapered instrument composed of a series of successively smaller cones set one on the other. The **tip** is sharpened.

N.B. In machine grinding a sharp rotating cutter removes triangular segments out of the round shank in the same manner as wood screws are made.

2. Its cross section is **rounded with one pointed projection**. The cone edges are **extremely sharp**.
3. It is more **flexible** than the k file or reamer because machining induces no work hardening as that produced by twisting.
4. The **Helical angle** is close to 90°. Thus the H file is used in **longitudinal filing motion** and is not a rotatory cutting instrument.
5. It is **more efficient** in filing than the K type file. This is because the cutting edge contacts the canal wall at nearly 90° as well as it has a positive rake angle creating a blade with cutting rather than scraping angle (see definition of rake angle later).
6. The H file has two drawbacks. It is weakened at each position of cone formation, resulting in **fracture** if the flutes bind in dentin and the handle **rotated**. The H file generally has sharper edges than the k file, it has tendency to **screw into** the canal during rotation.

   N.B. It can be broken if wedged against the canal walls and twisted. Bending of H file results in greater stress concentration; leading to crack propagation and instrument separation.
7. It can be used in preparing straight canals, immature teeth and the straight part of curved canals by **filing action**.
8. It can be used to remove loose instrument fragments, paper points from canals. The file is placed, rotated to hook into the point or fragment, and then pulled.

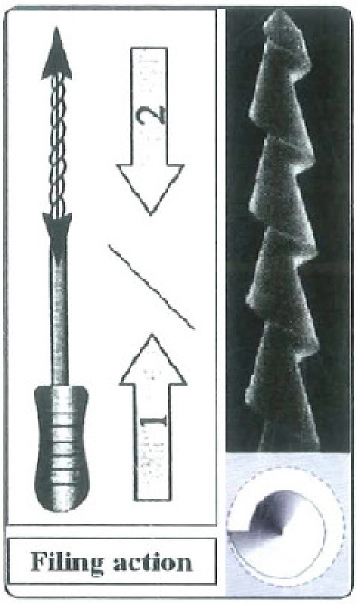


Fig. 8. H file; lateral view, cross-sectional view and mode of action

Rat Tail file or R –Type rasp, Fig. (9)

1. It resembles barbed broach in that spikes are cut into the shaft of flexible **soft steel** and project with their tip towards the handle. These spikes are more numerous shallower, smaller & nearly perpendicular to the shaft. It is tapered with **eight pointed polyhedron** cross section.
2. The **tip** is rounded.
3. It is used in **push-pull action** and cuts effectively on the pull stroke. Unfortunately it leaves the root canal rough and irregular.
4. It is **not widely used** today since barbs often fall off during instrumentation and end up in the root canal.

Barbed broaches and rasps are similar in the general design; however, broaches and rasps show significant difference in taper and barb size. The broach has smaller taper (0.7%-1%) compared to the rasp (1.5%-2%). Barb height is greater in a broach than in a rasp; because the barb is cut and elevated from the instrument core; the broach is much weaker than the rasp.

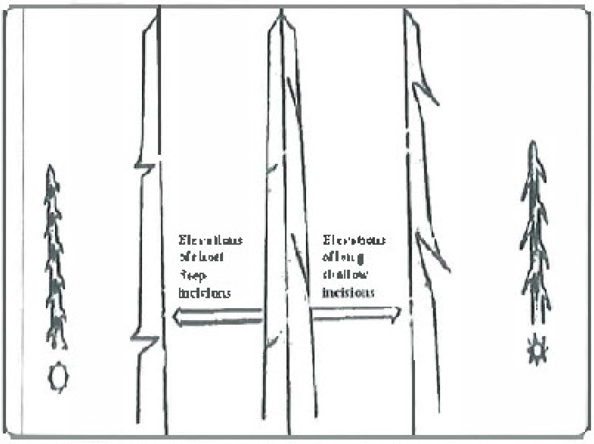


Fig. 9 Manufacturing of Rasps (left-hand side versus Barbed broaches (right -hand side)

5- STAINLESS STEEL INSTRUMENT DEFORMATION AND BREAKAGE Fig.(10).:

Permanent deformation of files and reamers occur when the instrument gets bound in the canal while the force of rotation continues. *Excessive clockwise* rotation of a locked instrument causes opening of the flutes, further clockwise rotation causes reverse spirals. On the other hand, *excessive anticlockwise* rotation of a locked instrument causes winding of the flutes more tightly. Both instruments can fracture when subjected to further rotation and MUST be discarded.

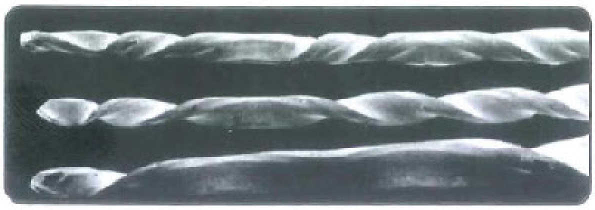


Fig. 10 Permanent deformations of K type instruments

6- HAND INSTRUMENTS' STANDARDIZATION

In 1957, Ingle established a logical nomenclature for standardized root canal instruments, so that all manufacturers could conform in length, width, and taper to a specific standards. The International Standards Organization (ISO) further developed this system.

Landmarks of standardized instruments are:

A-The length of the instrument

B-The numbering of the instrument

C-Incremental increase in size

D-Colour coding

E-Instrument taper

F-The tip angle

G- Tolerance (quality control)

A- The length of the instrument Fig.11

1. The position where the cutting edges begin on the instrument is called D° (originally D1), The flutes extend up the shaft for at least 16 mm to stop at position **D16** (originally D2).
2. The rest of the shaft has no flutes.
3. **The length of the whole instrument** from tip to handle is either 25 mm (most common) or 21 mm or 28 or 31 mm. Short instruments (21 mm) afford improved operator control and easier access to posterior teeth, third molar and in patients who can't open widely. The longer instrument (28 or 31mm) is used for longer roots as canines.

Remember: The length of the blade with cutting flutes (between D° and D16) is 16 mm regardless of total instrument length.

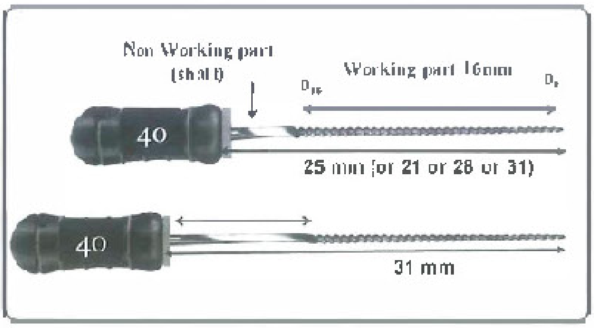


Fig. 11. Length of the cutting edges and the whole instrument. Note the increase of the smooth shaft length in the 31 mm long instrument.

B- The numbering of the instrument: The standardized instruments are manufactured from sizes 6 to 140. The number expresses the instrument diameter at tip flute D_0 in hundredths of millimeter.

Example:

Instrument number 30 has a diameter at D_0 = 30/ 100= 0.3 mm, and number 6 has diameter at D_0 = 6/100 = 0.06 mm.

C- Incremental increase, **Figure 12,** Instrument sizes facilitate the placement of the next instrument size in the canal up to the working length.

In small sizes from # 10 up to 60, the increment is 5/100 (0.05 mm or 50 microns) separating one instrument from the next.

In large sizes from # 60 up to 140, the increment is 10/100 (0.1 mm or 100 microns) separating one instrument from the next.

While from # 6 up to 10, the increment is 2/100 (0.02 mm or 20 microns).

A **total of 21 instruments** exist with the following sequence according to the above mentioned incremental increase in instrument diameter at D°

6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 70, 80, 90, 100, 110, 120, 130, 140.

Remember: The **name** of the instrument is its width at D° in hundredths of millimeter.

D- Six colour codings, **Figure 12,** white, yellow, red, blue, green, black are used sequentially on the handle of for easier identification of **sequence of size.**

Colour coding begins with white (#15), and then yellow (#20), red (#25), blue (#30), green (#35) and black (#40).

Colour coding is repeated up to instrument size 140, such that no. 15 and no. 45 and no.90 are all white.

In addition no. 6 is pink, no. 8 is gray and no. 10 is purple.

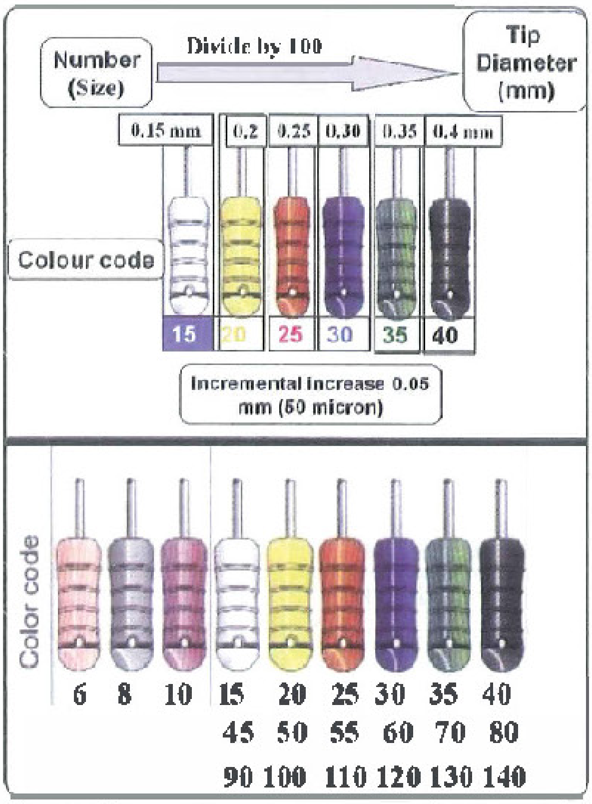


Fig. 12. Sizing and Incremental increase in instrument size and colour coding

E. The taper of the instrument (increase in diameter/mm along its working length), **Fig 13**

1. The taper (flare) of the instrument is the same regardless of the size of the instrument. Standard taper allows easier placement of instruments in small or curved canals

2. A standard **ISO taper** is set at 0.02 mm per mm (2%). At the coronal-most part of the working flutes, the instrument is 0.32 mm thicker than at D°. This is calculated by multiplying 16 mm (length of cutting flutes) by 0.02 mm = 0.32 mm.

Example: Instrument #15 with 0.02 taper would have 0.17 mm diameter after 1 mm from tip, 0.19 mm diameter 2 mm from tip and 0.21 mm diameter from 3mm from tip.

At the end of 16 mm working part, it has a diameter= D° + 0.32= 0.15+ 0.32= 0.47mm

3. Newer instruments made from nickel-titanium may exhibit other tapers in addition to 2% taper as 4%, 6%, 8%, 12%. This means that for every gain in length of the cutting blade the diameter increase by 0.04, 0.06,0.08,0.12 mm, respectively.

F. The tip angle, Figure 13, is standardized to be 75° ± 15°. This design provides cutting efficiency without an excessively sharp transition angle.

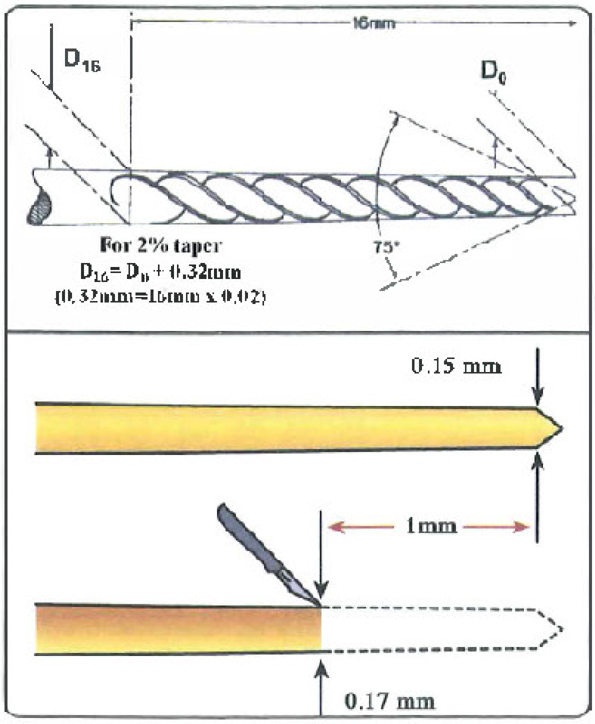


Fig. 13. Instrument taper and tip angle. Similar taper exists in standardized gutta percha cones.

G. Quality control (Tolerance):

An instrument is still accepted if it is within ± 0.02 mm of the standard at D^0. Therefore, a size 30 ideally is 0.3 mm at D^0 but may be as small as 0.28 or as wide as 0.32 mm. Accordingly, the diameter of two instruments with the same number may vary as much as 0.04 mm.

The filling material (gutta-percha cone) should be 0.009mm (9 microns) less than the corresponding instrument number.

The gutta-percha cone tolerance should be ±0.04 mm of the standard.

STAINLESS STEEL INSTRUMENTS WITH MODIFIED DESIGN

1- REASONS FOR INSTRUMENT DESIGN MODIFICATION

Hybrid or modified instruments were developed to suit the preparation of curved canals without the procedural errors such as change of the canal path (Ledge, zipped preparation, or apical perforation) or lateral strip perforation or instrument breakage.

A. Alteration of the shape of canal curvature due to the use of inflexible instruments, Figure 14

Treating teeth with severe curvatures require flexible instrument. Small stainless steel files # 10, 15, 20 have narrow diameters and have sufficient flexibility. They are able to traverse the curve with minimal difficulty with virtually no alteration in canal shape. However, shaping curved canals to only the small flexible instruments may not allow sufficient cleaning, and cause inadequate obturation.

As larger (#30, 35, 40), files are used, the **inherent stiffness** of these files enhance cutting dentin on the concave side of curvature, resulting in *canal transportation*. Each successive larger file opens up away from the curve near the tip. This irregular opening of the apical curve is called **zipping of the canal**. Preparation is not narrowest at the tip of the canal but rather several millimeters from the tip. The new narrowest part of the canal is called **the elbow**. A zip is wider than the elbow.

N.B. *Transportation* is the excessive loss of dentin from the outer wall of a curved canal in the apical segment. This procedural error can progress to perforation of the root canal.

B. Alteration of the shape of canal curvature due to instruments with active cutting tip

The instrument tip has two functions: to enlarge the canal and to guide the file to penetrate through the canal. Original K type file had a tip that resembled a pyramid. It was capable of lateral and apical cutting. If a file with a cutting tip is allowed to work too long in one position of a curved canal.

Stainless-steel files have an inherent stiffness that increases as the instrument size increases. When preparing a curved canal, the **stainless steel metallic memory** forces it to return to its straight position, especially when the operator uses a filing motion The energy stored by bending an instrument creates **restoring forces**. These forces are concentrated at the **cutting tip**, thereby cutting the outer dentin wall. Both instrument flexibility and design of cutting tip determine the transportation capability.

C. Strip perforation due to excessive and miss directed coronal flaring Figure 14:

In Mandibular molars, concavities exist on the distal side of the mesial root and mesial side of distal root. Excessive or misdirected flaring towards these dangerous concavities can lead to lateral **strip perforation**. This can be avoided be either by modifying the instrument or the technique of preparation. Thus avoiding excessive preparation on the bifurcation side of these root canals.

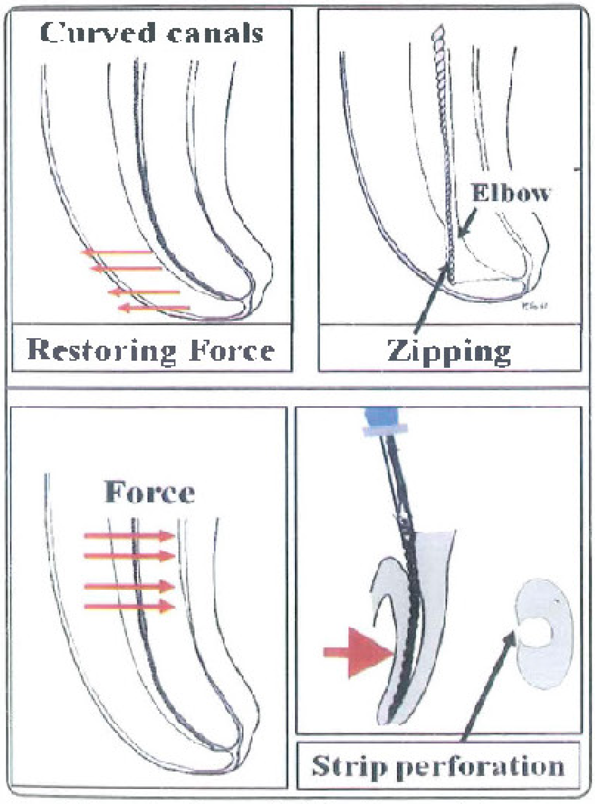


Fig. 14 Restoring forces of stiff stainless steel instruments can cause canal transportation in curved canals and strip perforation

It was thus necessary to develop new file designs to:

1. Increase flexibility,
2. Increase cutting efficiency,
3. Increase strength and thus avoid instrument separation.
4. Decrease procedural errors, strip perforation, canal transportation: zipping ledge, perforation
5. Decrease number of instruments needed during canal preparation.

2- HYBRID OR MODIFIED INSTRUMENTS' DESIGN INCLUDES

- A- Changing geometric dimensions and designs:
  - i. Changing cross-sectional geometry
  - ii. Changes in the depth or angle of the cutting edges of the flutes
  - iii. Variation in the design of the tip
  - iv. Variation in taper of instrument
- B- Variation in the method of construction (machining versus twisting),
- C- Using constant % change in dimension at D° rather than the linear mm changes
- D- Developing intermediated sizes
- E- Developing apical preparation type instruments
- F- Variation in the material of construction

A- Changing geometric dimensions and designs:

i- Changing the cross-sectional geometry

a- *Changing the cross-section of K type instrument from square to rhomboid .*

Kerr Manufacturing Company developed **K-Flex file**, **Fig (15)**, from a diamond shaped stainless steel blank, The flutes were produced by twisting to produce the cutting

edges as the k File. This rhomboid shape **decreased the cross-sectional diameter** (compared to the square cross section of K file) and **enhanced flexibility**.

In the lateral view between every other edge there is a high true cutting edge formed by the acute angles of the rhomboid shape and alternating low flute formed by the obtuse angle of the diamond. The working angles that cut dentin were approximately 80°, being **sharper** than the 90° angles of the K files. This enhances their cutting ability even though only two cutting angles were present.

The obtuse angles of the rhomboid shape **provided increased clearance space** between the working edges, so more debris would be removed by outward stroke. This reduced the possibility of compacting dentinal filings in the canal.

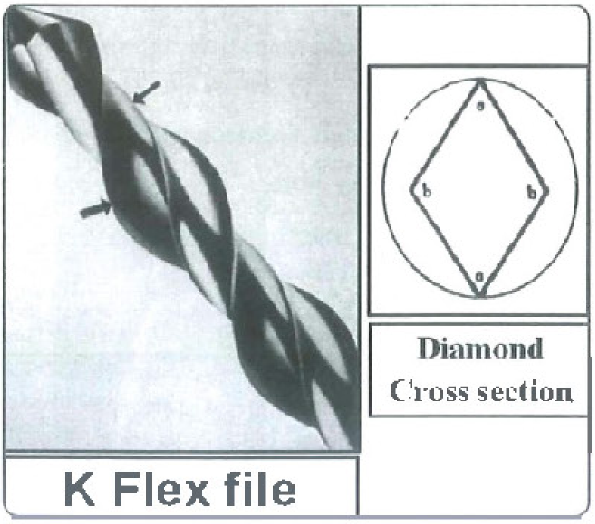


Fig. 15. K Flex file; lateral and C.S views

b- Changing the cross section of K type instrument from square to triangle **Fig (16)**

Flex-O-file, instrument utilized a triangular blank, as used for reamer, with flutes **twisted more tightly** to give more cutting edges, but maintaining the same **narrow cross-sectional** diameter for increased flexibility.

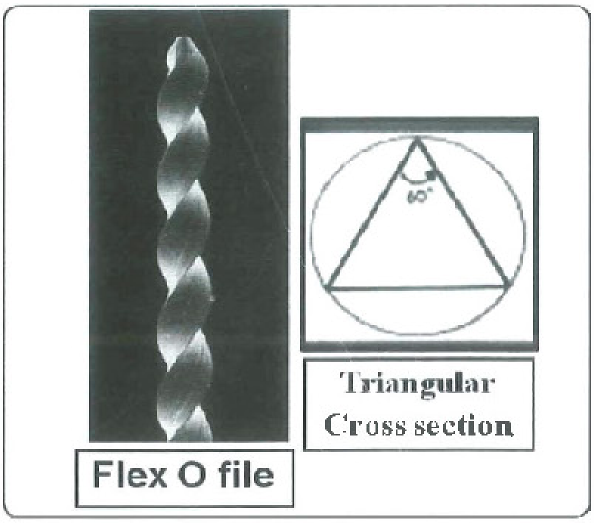


Fig. 6 Flex O file, lateral and C.S. views

c- U file cross sectional configuration:

The **U shape design** is recommended in NiTi instruments used in rotary motion such as: canal master U, Light speed, Profile series, and Profile GT, **Fig (17)**.

The radial lands provide the following functions: (1) They keep the instrument centered in the canal; thus reduce transportation. (2) They reduce the tendency of instrument to screw in. (3) They support the cutting edge and reduce microcracks propagation. (4) To reduce friction; some of the land area may be reduced (relief) as in rotary NiTi Quantic instruments. The **U shaped clearance space** helps in loading cut debris.

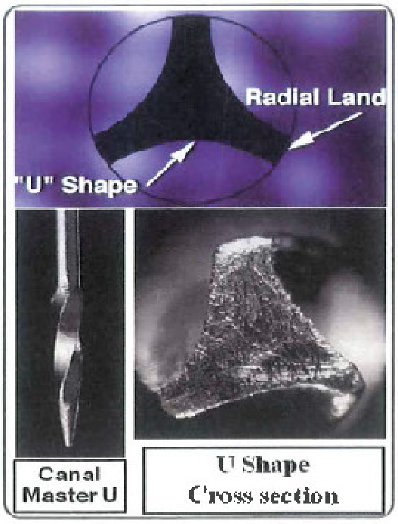


Fig.17. Canal master with U shape design

d- S shaped cross sectional configuration, **Fig. (18)**

UniFile and S file possess S-Shaped cross section. They are modification of the H type file. The S file displays a **double helix** ground into the shaft. This **doubles** the **number of cutting edges**. The flutes are less deep than those of H files, leaving greater bulk in the core shaft. The wide cross-sectional diameter **increased strength but decreased flexibility** compared to H file.

The helical angles of the flutes may remain uniform through the length of the instrument. **However, continuously variable helical angle** is also available. This variation **reduces** chances of the instrument to **thread itself (screw) into** dentin and then fracture on removal. Depth of flutes increases from tip to handle providing **increasing clearance space**. Sharp edges allow efficient cutting with withdrawal stroke. The slightly decreased helical angle (relative to H file) allows cutting by reaming as well (but not more than 1/4 turn).

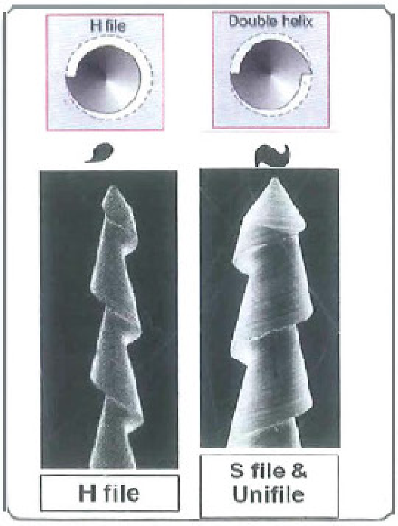


Fig.18. H file versus S and Unifile

ii- Changes in the depth or angle of the cutting edges of the flutes:

a- Safety H: The H file was modified, by providing it with non cutting side, to **prevent stripping** in curved canals, **Fig.19**.

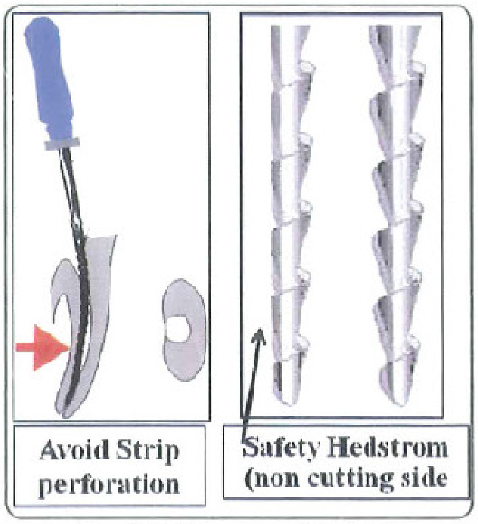


Fig. 19. H file versus safety H file

b- UniFile and S file possess as mentioned before either uniform helical angles of the flutes or **Continuously variable helical angle** to **reduces** the chances of **screwing into** dentin. The flutes are less deep than those of H files to increase strength.

c- A File, Fig (20), is a modified H file operated with automated Canal finding system (a contra angle that delivers both vertical and clockwise-anticlockwise motions). **It has the following features**:

(1) Steep depth of flutes, 40° helical angle of cutting blades, which cuts more efficiently than standard 60° or 70° helical angle of H file. When inserted in a curved canal, the steep blades on the inner concave wall collapse, and thus lose much of their cutting ability (**avoiding canal lateral stripping**). The blades on the external convex wall open up and can cut dentin. This is especially useful in preparing curved mesial canals of lower molars where the distal concave wall is often stripped.

(2) A non cutting tip on the instrument also ensures that instrument tip will follow canal path without causing transportation.

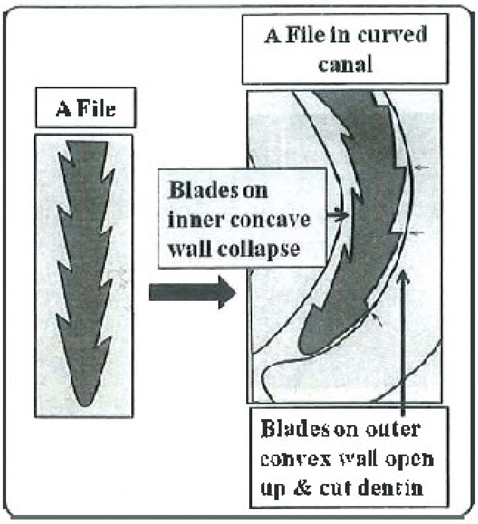


Fig. 20. A File is a modified H file operates with automated Canal finding system. It is designed to avoid lateral stripping & apical transpotation.

iii- Variation in the design of the tip (minimizes zipping), **Figure 21**

a- **Flex R file** is a modified instrument with **rounded non-cutting tip** it was designed by Dr **Roane**. The active cutting transition angle from the tip was reduced. Thus a compound angle (70° of the initial tip and a guiding collar angle of 35°) was formed. It is claimed that this causes the file to remain centered and cuts all circumference evenly. The file is guided through curvatures with less risk of gouging of the external wall and with reduced transportation.

The fluted edges of flex R file are **milled (ground)** rather than twisted. This process allows control of instrument flexibility and cutting efficiency.

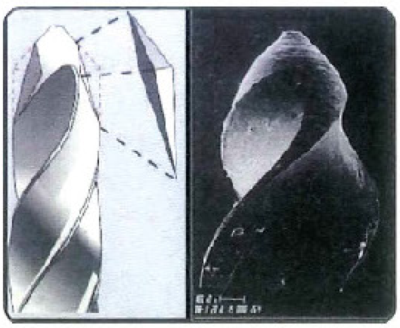


Fig. 21. Flex R file with modified tip design

b- Canal Master U, Light speed NiTi rotary instruments have similar modification where a pilot tip as used. A **non cutting tip of about 1.5 mm** is present, followed by several mm of cutting edges and then a narrower smooth shaft, **Fig.(22)**.

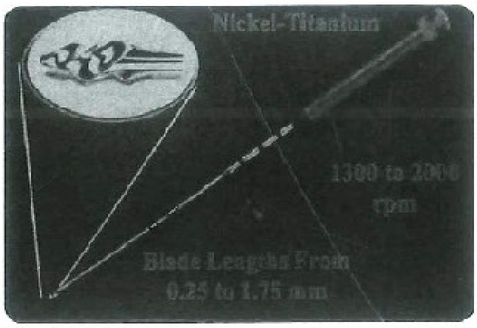


Fig. 22. Light speed NiTi rotary instrument

iv- Variation in taper of instrument, **Figure (23)**

Early flaring of the coronal portion of the preparation before completion of the apical portion can be performed by using Non ISO taper.

Preparation goes from coronal portion with large tapers, down through smaller taper near the apex. This is the principle of **crown down preparation approach** which can be applied with most rotary NiTi instruments to be operated with low speed high torque rotary handpiece. However, very large tapers or misdirected (towards the bifurcation side) can cause **strip perforation**.

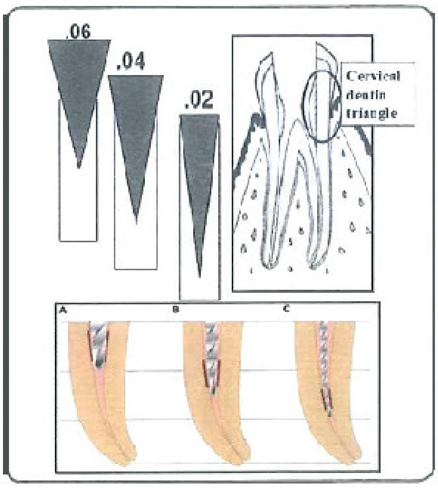


Fig. 23. Different tapers may aid in removing the cervical triangle and prepare the canal in a crown down approach

B- Variation in the method of construction (machining versus twisting), Fig 24

Using modern computer assisted grinding (milling) technology; it has been possible to grind from blank, stainless steel files similar in shape to twisted k files. These can be made with much **sharper blades** to enhance cutting qualities and with **deeper spaces** to allow the transport of more dentin shavings.

Milled stainless steel instrument **is more flexible** than a twisted one of same size and shape because the instrument shaft is not work hardened by twisting.

However, the sharp blade of milled stainless steel k files causes screwing in root canal and **breakage on** removal.

Milled K type and H type instruments are also available in **NiTi Alloy**, but **machining** defects and rolling over may appear at the cutting edges.

Instruments manufactured by twisting include: Stainless Steel K file, K Reamer, K flex file, K flex O.

Nickel Titanium TF (Twisted file).

Instruments manufactured by machine grinding: Stainless Steel H file, S file, Unifile, Safety H, Flex R. All NiTi instruments (except TF file).

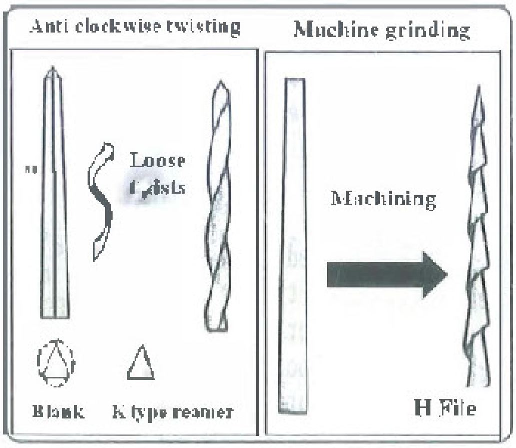


Fig. 24 Manufacturing of reamer by anticlockwise twisting and of H file by grinding.

C- Using constant % change in dimension at D° rather than the linear mm change

Dr Schilder designed a **constant percent change (29.1%)** at D° between successive file size rather than **linear mm dimension change** of the ISO standards.

In the ISO system, the dimensional increase from one instrument to the next when measured at D° is 0.02 mm (from #6 to #10), 0.05 mm (from #10 to #60), and 1.0 mm (from # 60 to #140).

Dr Schilder, showed that if D° of the ISO # 10 was compared to the next # 15 it represented large % Change (5/10 x 100=50%), and if the ISO # 15 was compared to # 20 it represented another % change (5/15 x100=33%).

He claimed that the 29 series with constant percent change (29.1%) was clinically better because first it spanned the range from # 6 to # 130 with **totally fewer instruments**: included 13 instruments (numbered 00, 0, 1 to 11) instead of 21 instruments in the ISO system, Second **more small instruments** were available and few large ones, **Fig. (25).**

However, the technique proved to be impractical in these small curved canals because there was major incremental increase where minor ones were needed. Size 4, corresponds to 0.21mm, and # 5 corresponds to 0.27mm, followed by # 6 which corresponds to 0.36 mm, Fig. (25). **Nowadays, only Profile 0.04 Taper series 29 rotary instruments** incorporated this system due to the drawbacks mentioned.

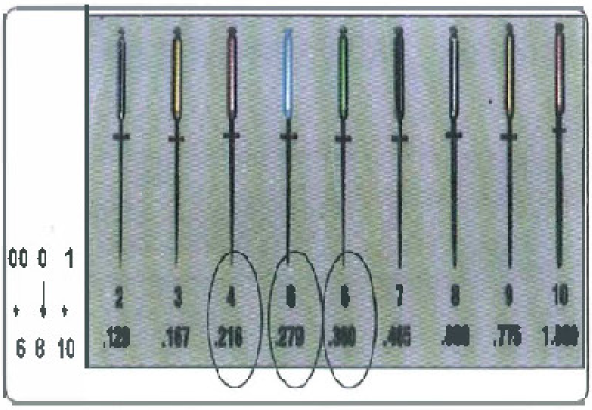


Fig. 25. Profile Series 29; more instrument at the beginning & few at the end.(13 instruments)

D- Developing intermediate sizes

Intermediate sized instruments are useful when treating small curved canals. **Golden Medium** are files manufactured with intermediate sizes in between normally manufactured ISO ones. They are manufactured according to ISO standardization. The files are available in sizes 12,17, 22, 27, 32,37, **Fig. 26**

According to **Dr Wein**, intermediate sizes can be custom made by clipping definite lengths from file tip: clipping 1 mm from size 15 (taper 2%), will result in size 17, further clipping of 1 mm will result in size 19. After clipping, re-bevel the instrument tip using diamond edge nail file.

Fig. 26. Golden Medium files

E- Developing apical preparation type instruments

It has been shown that transportation occurs during preparation because of the variability of cutting of dentin at the tip compared to the entire 16 mm cutting surface. The net result is tendency of deviation from original canal path; ledging and perforation. Instrument separation can also occur due to torsional loading with large frictional contact.

Canal Master System, **Fig. (27)**, having instrument with reduced cutting head and pilot (non-cutting tip) was thus developed for preparation of curved canals.

The instrument has: First a non-cutting pilot tip to limit transportation and guide the instrument through the canal. Second the cutting head is reduced from the standard 16 mm to 1-2 mm for maximal control of apical cutting. Third the diameter of the instrument's smooth round shaft is constant and is small to increase flexibility.

Original canal master was of stainless steel and was based on the K file design. Afterwards the blades became of the U shape design which is recommended for rotary motion. The Similar NiTi Rotary version developed is called Light speed.

Fig. 27. Canal Master U (Lateral view) and rotary NiTi Light speed instrument

F-Variation in the material of construction:

Different materials are being used to suit the different functions that must be performed by root canal enlarging instruments.

i- ***Small-sized carbon steel instruments for initial penetration*** of a narrow canal.

Calcified narrow canals are often lined by sclerotic dentin deposits that make the wall very irregular. **Pathfinder and C+ files, Fig.(28)**, were developed to negotiate highly calcified constricted canals. It resembles a file but with **narrower taper** to uniformly distribute the axial stresses along the instrument shaft, thus reducing the tendency to bend at the tip. They are available in small sizes and **made of carbon steel** that is reported to produce greater sharpness and strength for penetration. **Flexible instruments** are **poor in penetrating** the tip of narrow canal because it may bend on itself (buckle) just like a wet noodle.

Fig. 28. C+ file developed to negotiate highly calcified constricted canals

ii- Flexible instruments must be used to maintain the shape of the curve:

Flexible instruments are available, either by changing the design of the instrument made of stainless steel as previously illustrated or by using a more flexible material such as the Nickel Titanium alloy (NiTi).

ENGINE DRIVEN NICKEL TITANIUM ENDODONTIC INSTRUMENTS

In the 1960s, William F. Buehler and colleagues developed Nitinol wire; an acronym for the elements from which the material was composed; Ni for nickel, Ti for titanium and NOL from the Naval Ordnance Laboratory. It is more commonly referred to as nickel titanium or NiTi. The alloy is equiatomic mixtures of nickel and titanium (56:44 by weight). NiTi files are two to three times more flexible in bending and torsion, and more resistant to torsional failure than stainless steel.

NiTi instruments have *superelasticity* (rapid spring back upon deloading) and *high flexibility* (small force is required to deform material). Thus, they maintain the curved canals shape with less transportation compared to stainless steel files.

When used by hand, these files do very minimal preparation for given period of time. NiTi files are better used in special low speed torque control handpiece, to complete preparation in reasonable time.

1- Metallurgy of nickel–titanium alloys

NiTi can undergo solid phase transformations between three different crystalline structures: austenite, martensite and R-phase. This phase transition can be induced in both directions by applying temperature changes or by mechanical loading

The austenitic, parent phase, is the high temperature low stress phase (body-centred cubic lattice). The Martensitic, daughter phase, is the low-temperature high stress phase (closely packed hexagonal lattice).(Fig 29). R-phase is an intermediate phase between austenite and martensite

Phase transitions are responsible for the unique ability of Nickel-titanium (NiTi) alloys to recover their original shape after undergoing large deformations (up to 8%) through heating, known as *shape memory* effect, or through removal of the load, known as *superelastic effect.*

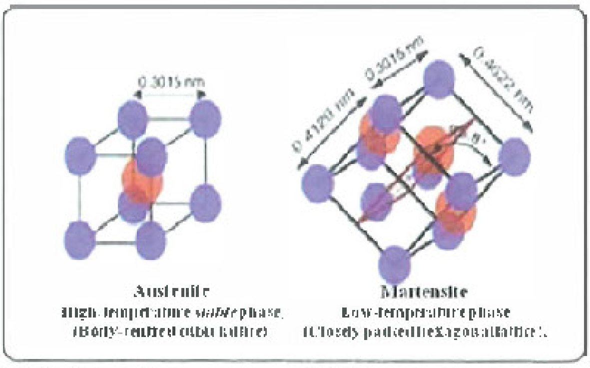


Fig. 29 Crystalline structures of NiTi; austenite, martensite.

Thermally-induced shape memory phenomenon: (Fig 30).

Austenite phase is a high temperature phase. When Nitinol is cooled through critical transformation temperature range it changes to twinned martensite (daughter phase). The alloys can be mechanically deformed in the low temperature martensitic phase to detwinned martensite. Deformation (up to 8%) can be reversed instantaneously by heating above 125°C.

The alloy "remembers" its original shape and returns to its pre-deformed austentic phase shape. This phenomenon is termed shape memory. The transition temperature range of

Martensite to austenite is in the range of –50 to+100°C. To set up a particular shape to be remembered (in austenitic phase), the alloy is initially shaped and annealed by heating at high temperature (500°C).

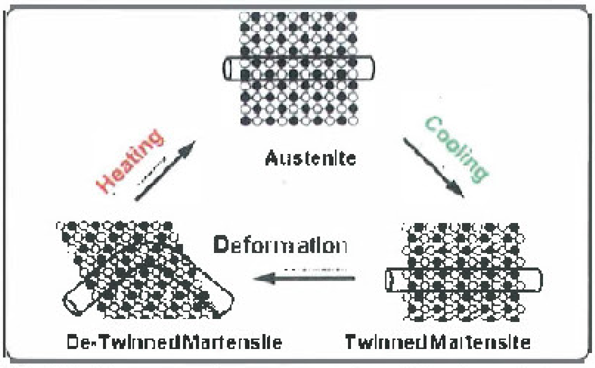


Fig. 30. Diagrammatic representation of the thermal shape memory effect of NiTi alloy. Shape memory recoverable strain is up to 8%.

Stress-induced Martensitic transformation (superelasticity):(Fig. 31).

A reversible transition from the austensitic to martensitic phase occurs as a result of the application of stress, such as during root canal preparation.

In the stress strain curve, **Figure 32**, The application of stress does not result in the usual steep proportional strain. As the application of stress reaches a specific level, a stress-induced martensitic transformation occurs, causing loading plateau, up to 8-10% strain. The rate of increase in stress levels off (plateau); due to progressive deformation. This results in the so-called super-elasticity. When the load is removed, spring back occurs to the previous shape with the reverse transformation from martensite to austenite Super elasticity of NiTi allows deformations of 8-10% strain to be fully recoverable (vs. 1% in stainless steel). If 8-10% strain is exceeded, the alloy will not revert to the original shape even when heated. Eventually, application of more stress results in more strain, up to breakage.

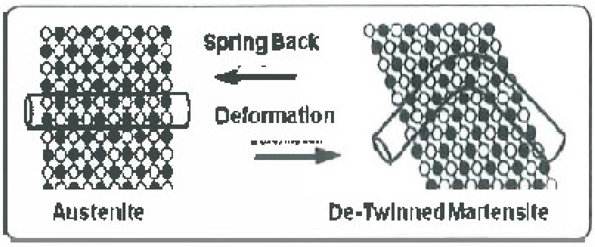


Fig. 31. Diagrammatic representation of the super-elasticity effect of NiTi alloy. Super-elastic recoverable strain is up to 8 10 %.

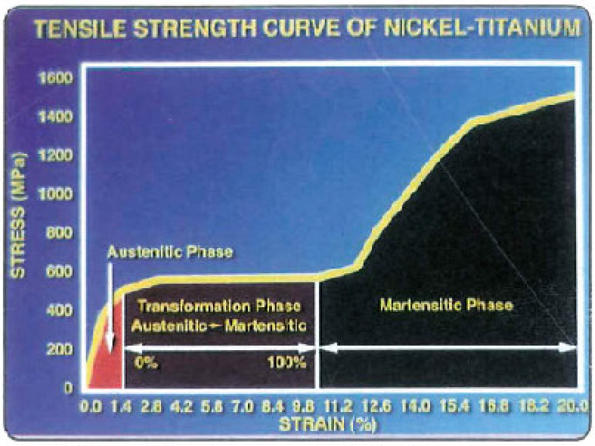


Fig. 32 Stress Strain curve of NiTi alloy showing the superelastic plateau region. Stress application induce austenitic→martensitic transformation and release of stress induces the martenstic→austenitic transformation. The R phase is an intermediate phase. Deformations involving as much as 8 10% strain is recovered

Remember: NiTi has two unique characteristics namely: **Superelasticity** is regain of original shape due to the reversible stress -induced austenitic to martensitic transformation. **Shape memory** is the regain of original shape due to the thermally induced martensitic to austenitic transformation.

2- Construction of NiTi instruments:

Super-elasticity of austentic NiTi means that it cannot maintain a spiral. Attempts to twist instruments would result in instrument fracture. Thus austenitic NiTi files are basically ground into different designs: H style, U shapes in different sizes and tapers. With the ability to machine flutes, many new designs are available with variation of tip, taper, cross

section, helical angle, pitch. Different designs affect instrumentation effectiveness and file susceptibility to breakage. **Figure 33**

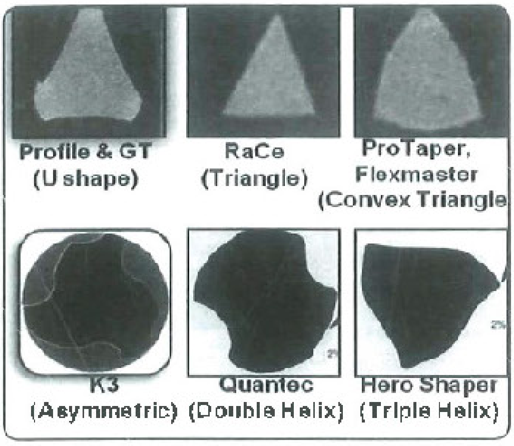


Fig. 33. Rotary NiTi files with different cross sectional shapes, core diameter, rake angles.

Variation in designs of rotary NiTi instruments Figures 34-36:

These includes

1. **Taper:** amount of file diameter increase each mm along its working part from tip to handle. Different tapers are available. Determining the cross sectional diameter in the point of curvature can help to estimate the relative stress being placed on the instrument.
2. **The helix angle:** the angle between the cutting edge (blade) and the long axis of the file. Variable helical angle decreases screwing effect.
3. **The cutting edge (blade) of the file:** its effectiveness depends on the angle and incidence and sharpness.
4. **Flutes are grooves on the working part.** Each extends from cutting edge to cutting edge. Its width and depth determines the amount of collected dentin chips that is removed from canal wall.
5. **The pitch:** The distance between a point on the leading edge and a corresponding point on the adjacent edge. The shorter the pitch, the more spirals, the greater the helix angle. Having variable pitch decreases the screwing effect.
6. **The marginal radial land:** a surface projecting from the central axis as far as the cutting edge between the grooves. The land touches canal walls at the file periphery and reduces the tendency screwing into the canal, reduces transportation, reduces the propagation, of microcrakes on its circumference, supports the cutting edge.
7. **The relief:** To reduce the frictional resistance, some of the surface area of the land that rotates against the canal wall may be reduced to form a relief.
8. If the file is sectioned perpendicular to the long axis, the **rake angle** is the angle formed by the blade and the radius of the file. **Positive or cutting rake** angle: if the angle between the blade and the surface to be cut is obtuse. **Negative or scraping rake** angle: if the angle between the blade and the surface to be cut is acute.

N.B. However a drawback of the machining NiTi rotary instruments from starting wire blanks are rollover at the edges and variety of surface defects: machining grooves, microcraks, surface debris. Surface cracks increase the stress concentration, with the possibility of crack initiation and propagation and ultimately instrument fracture. **Figure 37.**

Fig. 34. Different tapers are available for rotary NiTi. File size in the point of curvature estimates relative stress there.

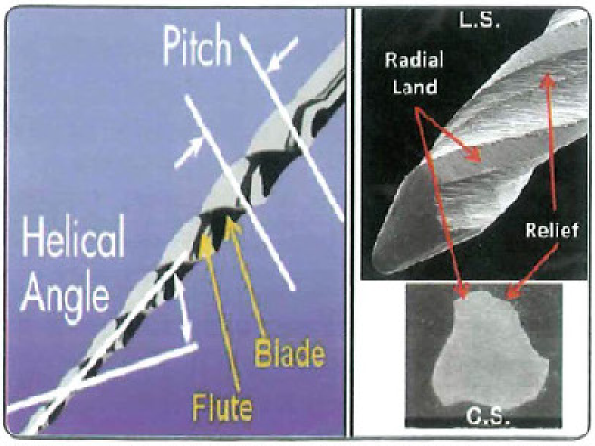


Fig. 35. lateral aspect of NiTi instrument showing Helical angle, cutting edge (blade), flute, Pitch radial land, and relief

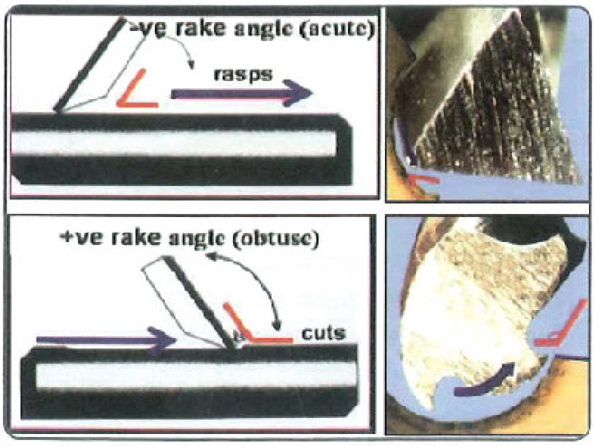


Fig 36. Different rake angles produces different cutting processes of dentin. Section perpendicular to long axis is rake angle. Or perpendicular to blade is effective rake angle.

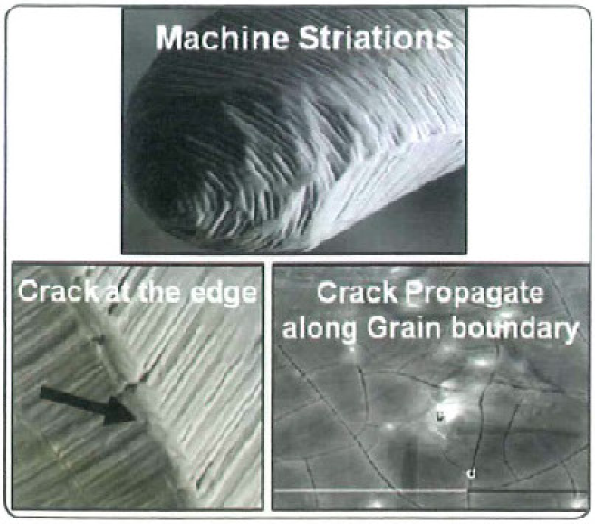


Fig. 37. Defects of NiTi instrument from machining process

3- Modes of Fracture of rotary NiTi instruments

Though highly flexible and having better ability to maintain the canal shape, a disadvantage of NiTi alloy is that it is more susceptible to fracture.

Two main distinct modes of fracture exist, **Figure 38**

A. Torsional failure: Torsional fracture occurs, when the tip of the rotating instrument binds in the canal while the motor continues to rotate. Torsional fracture occurs when the ultimate strength of the material is exceeded. Taper lock occurs when the shape of the tapered root canal becomes similar to the instrument in use. The instrument may be locked and the tip fracture. *Larger taper and sizes have greater torsional strength*. Working with the instrument in a suitably adjusted torque of the low speed torque controlled motors, can reduce torsional failure.

B. Flexural cyclic fatigue Failure: continuous rotation in a curved canal subject the instrument to metal fatigue due to repeated loading with tensile loading on the outer curve and compression on the inner curve. *Larger taper and sizes have shorter fatigue life especially when rotated in sharp curves, and for a long time.* Each instrument has a fatigue life span with approximate number of cycles to produce failure. Hence using the lower speed (revolution per min rpm) advised by the manufacturer, can reduce the incidence of fatigue failure. This occurs due to the extension of the time needed to reach the number of cycles to fracture.

C. Torsional fatigue Failure also occurs when the instrument is repeatidly bound and released by canal irregularities below its torsional strength. As when the clinician is using high pressure and the motor is repeatedly performing autoreverse.

N.B. Total fatigue life consists of 3 stages; *(1) crack initiation, and growth along grain boundaries followed by (2) crack propagation, until (3) the crack reaches the point where the remaining material is overstressed overload zone results. The overload zone reveals a dimple rupture.*

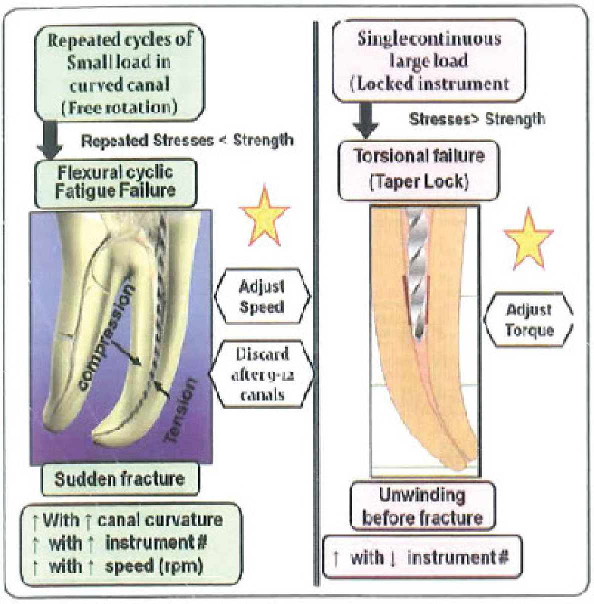


Fig. 38. Flexural cyclic fatigue can occur from continuous rotation in a curved canal Torsional failure can result from locked instrument.

4- Potential factors influencing fracture include:

A- Manufacturing strategies,

B- Clinician handling,

C- Root canal anatomy (position & degree of curvature).

A- Manufacturing strategies to improve clinical performance of NiTi rotary instruments include:

i- Changing design

ii- Surface treatment

iii- Changing manufacturing procedure

iv- Thermo mechanical treatment

v- Different kinematics (file motion)

vi- Single File systems

vii- Glide path NiTi rotary files

i- Changing design

- **Apical cutting head**: light speed and light speed LSX instruments
- **Rotary instruments with increased taper** 4%, 6% as profile. GT and GTX, HERO instruments
- **Rotary instruments with specific designs** as **Protaper** (progressive taper),
- **RaCe** and **Bio RaCe** (spiraled & non spiraled segments and electropolished with different taperes),
- **K3** (asymmetric cross section with different taperes, positive rake, radial land and relief),
- **Endosequence** (alternating wall contact points and electroplished with different tapers).
- **RevoS, Protaper next, One Shape:** Asymmetric design with swaggering motion. The center of rotation is offset. In rotation, the files produce a mechanical wave of motion that travels along the active length of the file. This snake like movement allows better debris evacuation, less stress on instrument, flexible, negotiate the canal.

ii- Surface treatment

Aiming to eliminate surface defects and machine stations, produce harder surface and improve the resistance to cyclic fatigue and improve cutting efficiency of endodontic instruments. Strategies include electropolishing, and ion implantation with titanium nitride. example: RaCe, Endosequence. **Figure 39.**

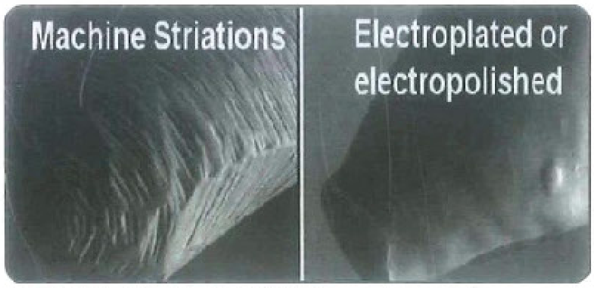


Fig 39 Electroplated NiTi instrument to create a smooth surface devoid of the machine striations

iii- Changing manufacturing procedure

The TF (Twisted file) was introduced in 2008. It is a NiTi rotary file manufactured

using a twisting method (of R phase), rather than machining. It is fabricated by 2-step transformation; initially transforming austenite NiTi wire into the R-phase through a thermal process. *Once the R-phase is identified, wire in this state can be twisted.* After additional thermal procedures to maintain its new shape, the instrument is *converted back into the austenite phase, which is superelastic once stressed.* This file is reported to have better flexibility and fatigue resistance.

Electrical discharge machining (EDM): The shape of the file is formed by electric spark erosion of a wire. EDM manufacturing alters the molecular structure on the file's surface. Spark erosion gives better hardened surface with better flexibility and fatigue resistance. E.g. CM wire of Hyflex EDM

iv- Thermo mechanical treatment of NiTi

Conventional NiTi alloy is present in the austenite phase at room temperature. Thermomechanical treatment of NiTi alloy allows different proportions of stable martensite and R-phase to be distributed throughout the austenitic matrix, at room temperature. This renders the alloy more flexible and more resistant to fatigue failure. Several thermomechanically treated NiTi alloys include: ***M-wire*** (e.g protaper next, Wave One, ***R-phase*** (e.g. K3XF) , and ***CM wire*** (controlled memory; e.g. Hyflex, Hyflex EDM). Significant increase in fatigue resistance is as follows: CM technology > M wire > conventional NiTi.

Thermal treatment causes increased Martensite to austenite transformation temperatures, thus allow stable martensite to exist at room temperature. The austenite transformation temperature of CM Wire is 55°C, M Wire is 50°C, TF is 17°C, and conventional SE NiTi wire is16–31°C.

The mechanical behavior of NiTi alloy is determined by the relative proportions and characteristics of various phases. Austenite is quite strong, hard. It is less flexible than martensite, but superelastic allowing up to 8-10% recoverable elastic deformation. Unfortunately, it has low fatigue resistance. While in the martensitic phase, NiTi alloy is very flexible, soft and ductile. It can easily be deformed, pre-curved to negotiate curved canals or bypass ledges. Martensitic files have significant increase in fatigue resistance and have extended lifespan. Modulus of elasticity of the martensitic phase (50 GPa) is less than the austentic phase (120 GPa). The R-phase shows superelasticity and shape memory effects; its elastic modulus is lower than that of austenite.

M-Wire (introduced in 2007) has nano-crystalline martensite grains evenly distributed inside austenite matrix.

CM-wire (introduced in 2010) is a mixture of martensite, R-phase, and a small amount of austenite. It is extremely flexible and memory of its shape can be controlled. It can maintain a precurved shape without rebouding to its original shape i.e does not exhibit conventional NiTi superelastic properties during the loading/ unloading. Yet they recover their shape on heating above the transformation temperatures. This is because heating transforms the metal temporarily into austenitic phase and makes it superelastic, and capable to regain its original shape before cooling down again.

A hybrid (austenite-plus-martensite) micro-structure, exhibit favorable fatigue resistance compared with a fully austenitic microstructure because of the increased number of interfaces. These cause the formation of secondary cracks, which can dissipate the energy required for crack propagation. In addition, the presence of these martensitic structures cause hardening of the heat treated alloys, so that torsional resistance of endodontic instruments made of M wire and CM is not compromised.

Gold process is a post-manufacturing procedure in which ground NiTi files are heat treated and slowly cooled. Transformation temperatures of austenite phase are modified giving a gold finish; with intensify fatigue strength & flexibility; e.g Protaper God, Wave One Gold.

Blue thermo mechanical treatment optimizes flexibility and fatigue resistance; e.g Vortex Blue and reciproc blue. The blue-color is due to hard titanium oxide surface layer on the Vortex Blue surface during manufacturing process.

R-phase technology: thermal treatment to NiTi files after grinding austentic phase; producing instrument of R phase. This improves flexibility and resistance to cyclic fatigue. Example: R phase K3XF with the basic features of austenitic K3 Numerous small micropores exist on the surface of K3XF. These pores do not contribute to the failure, but serve as a local stress/strain discontinuity from which crack nucleates.

XP endo finisher files: **MaxWire (Martensite Austenite electropolish flex)..** It is highly flexible. The files operate by shape-memory principle. It is straight in Martensitic phase at r.t. When inserted in the canal, and heated to body temperature, it changes its shape due to its molecular memory to the curved austenitic phase. The austenitic phase shape in the rotation mode expands and allows the and remove debris from those hard-to-reach areas (oval canals). Figure 40

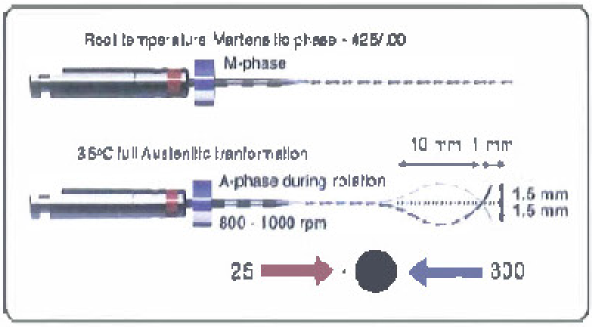


Fig. 40 XP endo Finisher

v- Different kinematics (file motion)

Most commercially available files are mechanically driven in continuous rotation. However, ***oscillation***, defined as equal repetitive back-and-forth motion, has been clinically utilized to drive stainless-steel files since 1958. Initially, files rotated in large equal angles of 90° clockwise (CW) and counterclockwise (CCW) rotation. Currently, the M4 (SybronEndo), Endo-Eze AET (Ultradent), are examples of oscillation systems that utilize small, equal 30° angles of CW/CCW rotation.

Reciprocating unequal CW/CCW angles can enable a single reciprocating NiTi file to shape canals. WaveOne (Dentsply Tulsa Dental Specialties and Dentsply Maillefer) and Reciproc (VDW) are examples of reciprocating single-file shaping techniques. Both files are made out of M-wire. Strategically, Fatigue resistance is improved because after three CCW (150°) and CW (30°) cutting cycles, the file will have rotated 360°, or one complete circle. This novel reciprocating movement allows a file to progress more readily without the risk of a screwing effect, and cut efficiently.

TF adaptive: It uses the principle of rotary when you want, reciprocating when you need. Elements Motor with Adaptive Motion Technology rotates clockwise and when increasing load is met it adapts and reverses counter clockwise. It is used with TF file. It can be utilized in brushing action for preparing oval canals. It reduces apical extrusion of debris as the CW angle is greater than CCW (370 vs 50).

Self Adjusting file (SAF) is attached to a modified Kavo handpiece used by in and out vibration, 5000/min. It is an instrument made as a hollow thin NiTi lattice cylinder that is compressed when inserted into the root canal and adapts to the canal cross section, even the oval shaped. Continuous irrigation is applied via a special hub on the side of its shank.

vi- Single File systems

These use only a single file to shape the canal. However, more time is needed to focus on irrigation. Examples include.

1- Single file systems that use continuous 360° rotation; with or without glide path

e.g. One shape, F6 SkyTaper (F6ST): (conventional NiTi, Grinding)

Neolex: CM wire, EDM

2- Single file reciprocating systems: Wave one, Reciproc (M wire), Waveone gold. Sendoline S1

3- Single file Vibratory system: SAF

vii- Glide path NiTi rotary files

Scouting the root canals with small hand stainless steel files (#10,15) before rotary NiTi files is beneficial to reduce fatigue. NiTi for glide path management include:

- Path file (#13, #16 and #19, 2%)
- Scout Race (#10,#15,#20, 2%)
- G files (#12, #17, 3%)
- Pro. Glider (#16, 2%)
- Hyflex GPF (#10, 5%).

B- Clinician handling:

i. Adjust the specific speed (250-500 rpm) torque and auto reverse

ii. Use instruments in a well irrigated and lubricated canal.

iii. To avoid taper lock, use light pressure (450 g), advance in 1 mm increment →if additional pressure is needed →change to smaller size & taper or circumferentially file coronal to this position.

iv. To avoid fatigue failure: use pecking motion once the working length is reached then immediately withdraw

v. Beyond the point of curvature in the apical zone, the file diameter should be no greater than .60mm for a 2% taper, .55mm for 4% taper, .50mm for 6% taper, and .35mm for 8% taper.

vi. Clean flutes and check for signs of distortion or wear.

vii. Follow manufacturer recommendation of the maximum number of usage of approx 9 canals or less if it was overly stressed in severely curved canal.

viii. Review canal anatomy and use the instruments cautiously in acute bends.

MOTORS USED IN ENDODONTICS

1- GEAR REDUCTION, TORQUE CONTROL MOTORS FOR ROTARY NITI INSTRUMENTS

Most NiTi rotary instruments operate at very low speed 300-500rpm. (Light speed NiTi instrument operate at 1200 rpm)

Electric motors with adjustable gear reduction are more suitable for rotary NiTi systems than their air hand pieces counterparts as they ensure a constant rpm level, **Figure 41**. It is worth noting that regular low speed motors operate at 20,000 to 40,000 rpm.

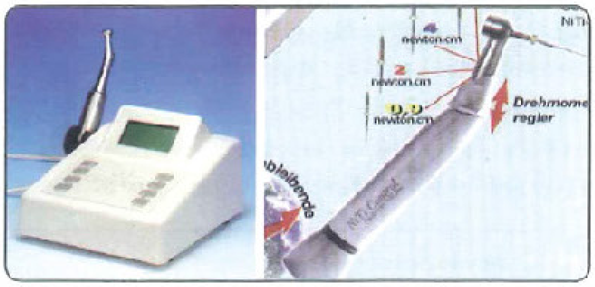


Fig. 41 Electrical and air driven gear reduction hand pieces

2- ENGINE DRIVEN RECIPROCATING MOTORS AND INSTRUMENTS Figure 42

The Giromatic handpiece delivers 3000 1/4 turn reciprocating movement/min. This motion is claimed to decrease the torsional load on the instrument compared with full rotation handpiece. K-type and H-type instruments can be used.

Oscillating handpieces* for file systems** e.g SafeSider and Endo-EZE as well as the ***reciprocating motors for Wave one and Reciproc, ***Adaptive motors*** for TF adaptive are also a recently introduced modification for Giromatic handpiece principle.

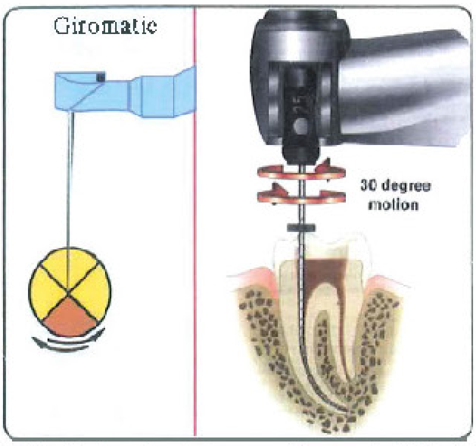


Fig. 42 Oscillating handpieces as Giromatic (left side) and safe sider (right side)

3- LOW SPEED ROTARY HANDPIECE AND INSTRUMENTS

In addition to regular burs, burs with extended shanks for low-speed contra-angle are useful for providing visibility during deep preparation of the pulp chamber. This is particularly important when using an operating microscope.

Straight line access from canal orifice to the initial point of canal curvature can be accomplished by using rotary instruments as the **Gates-Glidden (GG)** Drills, **Figure 43** Each instrument has a long, thin shaft with parallel walls and short cutting head. They are manufactured in a set and numbered 1 to 6 (with corresponding head diameters of 0.5 to 1.5 (or 0.4 to 1.4) with incremental increase of 0.2 mm between each successive instrument). The number of rings on the shank identifies the specific drill size. They are available in 32-mm and 28-mm length for posterior teeth.

Fig. 43. Gates Glidden Drills

GG drills are side cutting instruments with safety tips; they are used to cut dentin as they are withdrawn from the canal. They are used in the straight portion of the canal, serially and passively.

Two procedural sequences have been proposed: (1) crown down sequence starting with large drills progressing to smaller ones, **Figure 44**, (2) Step back technique and progressing to smaller ones.

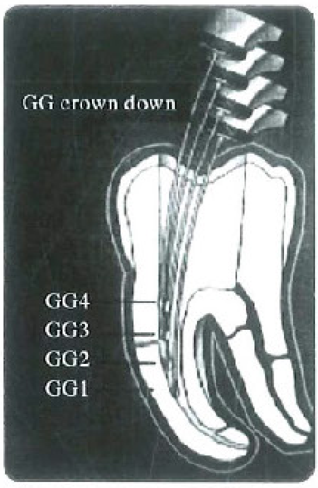


Fig. 44. Gates Glidden Drills used for Crown down approach

Their cutting should be directed away from external root concavities in single-rooted and furcation teeth; to avoid coke bottle-like preparation or strip perforation. High revolution and excessive pressure may cause the instrument to fracture. The cutting head may fracture under high torsional load. GG drills may be safely used with regular low speed motors, **Figure 45.**

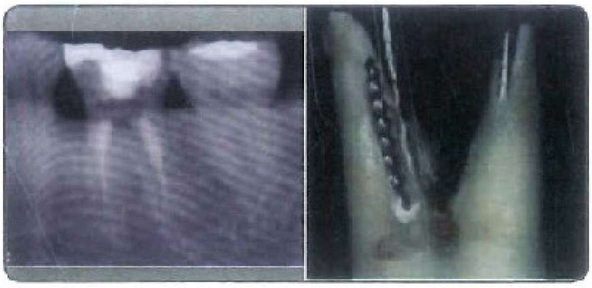


Fig. 45. Over preparation by Gates Glidden drills causing Coke bottle appearance (above), and lateral strip perforation (below)

4- SONIC AND ULTRASONIC DEVICES AND INSTRUMENTS

Ultrasonic and sonic devices activate an oscillating sinus wave-like fashion in the file with a frequency of 25-30 KHz and 2-3 KHz, respectively.

Ultrasonic devises use regular types of instruments (e.g. k-files), whereas sonic devices use special instruments as Rispi-sonic, shaper-sonic, Trio-sonic, **Figure 46**.

Ultrasonic devices include magnetostrictive Cavi-Endo and The piezoelectric ENAC and P5 Neutron Piezoelectric devices generate less heat and transfer more energy to the file, than magnetostrictive, making it more powerful.

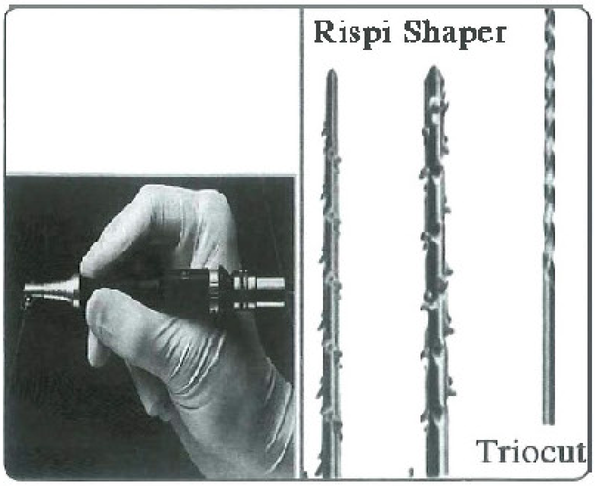


Fig. 46. Sonic handpiece with three specially designed instruments

Ultrasonic devices are not recommended for root canal preparation. They suffer the following disadvantages: 1-Loss of tactile sense, 2-Canal blockage, 3-Canal ledging, 4-Canal perforation, 5 Instrument breakage. However, ultrasonic devices do improve the **ability to clean the pulp space and difficult to debride** areas through acoustic streaming. During free ultrasonic vibration in a fluid **acoustic streaming** creates small intense, circular fluid movements (i.e. eddy flow) around the instrument. The eddy occurs closer to the tip than in the coronal end of the file, with an apically directed flow at the tip. Acoustic streaming increases the cleaning effect of the irrigant in the pulp space.

Free vibration of small files (#15 or #20) or Blank (non cutting inserts) is necessary to avoid contact with canal walls during vibration. Depending on the size and power, the file tip may have amplitude that requires a **canal size of at least #30 file through #40 file for free oscillation**. As any contact with the root canal walls dampen the oscillation, **Figure 47.**

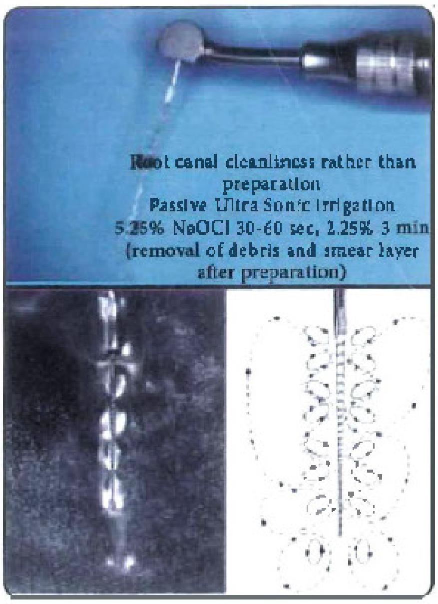


Fig. 47 Passive Ultrasonic irrigation causes acoustic streaming which increases the cleaning effect of the irrigant.

New tips for piezoelectric ultrasonic units have been effective during access cavity preparation in dentin removal in the pulp chamber and uncovering orifice of the canals, **Figure 48**.

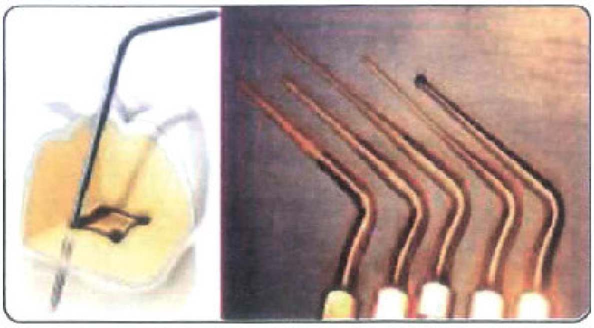


Fig. 48. Several ultrasonic tips used during access cavity preparation for uncovering dentin shelves covering canal orifices

Self Adjusting file (SAF) is an instrument made as a hollow thin NiTi *lattice cylinder* that is compressed when inserted into the root canal and adapts to the canal cross section, even the *oval shaped*. It is attached to a *vibrating* handpiece. Continuous irrigation is applied a special hub on the side of its shank. **Figure 49**.

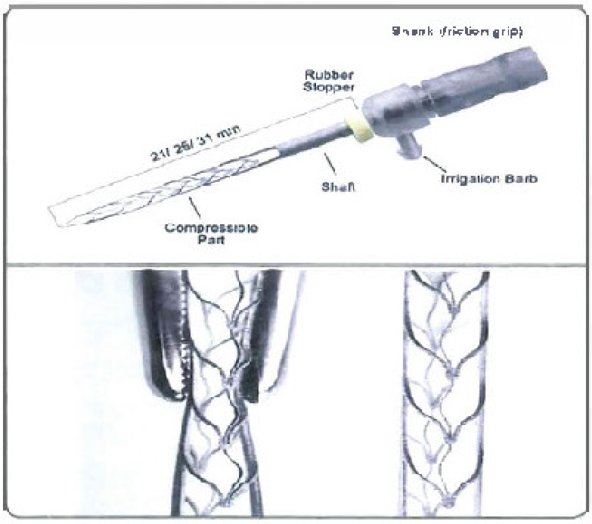


Fig. 49. Self Adjusting File (SAF)

CHAPTER REVIEW QUESTIONS

1. List the basic set of instruments appropriate for: Access prep, exploring root canal orifices, root canal prep, obturation.
2. Explain the basis for sizing and taper (standardization) of size 35 k type hand operated instruments
3. Describe the differences between k reamer, k file, H file regarding: material of construction, manufacturing procedure, longitudinal design (helical angle, flute number, clearance space) cross section, tip configuration, flexibility, cutting efficiency, mode of action, place of action..
4. Describe visible changes of instruments and causes that predispose to breakage.
5. List and differentiate between conventional and files of alternative design
6. Analyze the difference between Stainless Steel and Nickel Titanium instruments
7. Describe the action and use of rotary instruments in root canal preparation
8. Describe innovations in NiTi instruments and mode of fracture
9. List some reciprocating and vibratory instruments used in root canal preparation.

REFERENCES

1. Walton RE, Torabinejad M. Principles and practice of Endodontics, W.B. Saunders company, 2015
2. Cohen S, Burns R C. Pathways of the pulp, Mosby, 6th edition 1994, 8th edition 2002, 11th edition 2016.
3. Ingle I, Bakland LK. Ingle's endodontics, Wiliams & Wilkins Inc, 4th edition 1994, 6th
4. Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics, BC Decker Inc, 6th edition 2008
5. Wein F. Endodontic therapy, Mosby, 6th edition 2004.
6. Shen et al. Current Challenges and Concepts of the Thermomechanical Treatment of Nickel-Titanium Instruments. J Endod 2013;39:163–172.
7. Haapasalo M, Shen Y. Evolution of nickel–titanium instruments: from past to future. Endodontic Topics 2013, 29, 3–17.
8. Gambarini G, Cary Glassman G TF adaptive: A novel approach to Nickel-titanium instrumentation "Rotary when you want it, Reciprocation when you need it" Oral Health 2013; 22-30.

13 Cleaning and Shaping

Alaa El Din Diab

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identifying root canal treatment principles.
2. Integration of biological and mechanical objectives.
3. Recognition of procedural limits .
4. Evaluation and criticism of classic and modern techniques of working length measurements.
5. Determining and deciding the role of radiographic examination during cleaning and shaping procedures.
6. Identification and evaluation of different materials and devices used for root canal irrigation and bacterial control.
7. Identifying different technical difficulties during root canal treatment.
8. Studying and criticizing the different root canal preparation techniques .
9. Understanding the different instrument maneuvers during canal preparations.
10. Evaluating the different principles and techniques of mechanized instrumentation.
11. Overviewing rotary instrumentation systems, devices and techniques.
12. Determining the ideal criteria of prepared root canals before obturation.

Postgraduate students should be able to

1. Understand the concepts of designing and modifying instruments and its effect on cleaning and shaping procedures
2. Study the metallurgic properties of alloys used to manufacture endodontic instruments and how to alter these properties.
3. Utilize and combine their knowledge about pulp morphology, endodontic instruments and cleaning and shaping procedure to produce the best possible clinical outcome .
4. Criticize and evaluate the newly produced endodontic instruments so as to utilize and perform in the best and ideal way to producing ideal canal preparations.
5. Understand that simplifying the shaping procedures may have compromised cleaning outcome that needs compensation measures.

Chapter Outline

The ultimate goal in endodontic treatment is to perform a three-dimentional fluid tight seal to the prepared pulp space both coronally and apically. Upon the completion of the coronal access cavity, intraradicular cavity preparation is initiated.

The root canal system must be cleaned and shaped, cleaned of organic and inorganic irritants and shaped to receive a three-dimensional hermetic filling. Debridement is the terminology referring to the cleaning of the inside of the necrotic root canal system whereas extirpation refers to the cutting and removing of vital pulps. The principle of debridement is simple;instruments should plane all the walls and loosen debris, irrigants then flush all the loosened and suspended debris from the canal space. The chemical action of the irrigant further dissolves the organic remnants and destroys microorganisms in what we call chemicomechanical preparation of the canal.

Extirpation, on the other hand, requires a specially-designed instrument (barbed broach) that penetrates the pulp tissues,entangles the fibrous structure and removes it in toto.

Treatment objectives

For better understanding of the proper cleaning and shaping, we should first review our objectives. Herbert Schilder, introduced these objectives more than 25 years ago.

(a) Mechanical objectives:

1 Develop a continuously tapering conical form in the root canal preparation with the narrowest part apically and the widest part coronally.

2 Preserve the natural curve,cross section and taper of the canal.

3- Preservation of the apical foramen (never transport the foramen).

4- Creation of an apical stop (seat) which helps to confine the instruments and materials to the canal space and create a barrier against which gutta-percha can be condensed.

These mechanical design objectives are concerned during the shaping and enlargement of the canal system, however, other merits should be also fulfilled during canal preparation which are:

(b) Biological objectives:

1 Total removal of organic and inorganic debris in root canal system.

2- Sterilization of the root canal system.

3- Do not harm the tooth or the periodontium.

In order to standardize the procedures G.V. Black has set certain principles and steps that are to be followed during cleaning and shaping of root canals:

Principles for radicular cavity preparation (G.V. Black)

* ***Irrigation:*** of the access preparation to eliminate as much debris as possible before introducing the enlarging instruments inside the canal. This will minimize the number of microorganisms to be forced apically, and hence minimize postoperative pain, lubricate the canal for penetration by files and remove blood,pus or exudate so improves visibility and examination of the pulpal floor.

* ***Resistance form:*** this is to be achieved by enlarging the apical terminus of the canal while preserving the apical constriction. Violating the apical constriction by over-instrumentation leads to irritation of the periapical tissues by instruments and filling materials. In addition, the absence of an apical stop due to violation of the apical constriction results in an inability to compact the root canal filling material(like condensing amalgam in a class II cavity without a matrix).

* ***Retention form:*** this is achieved by enlarging the apical terminus of the canal while retaining its round cross-section. This shape provides an intimate contact between the apical dentin walls and the gutta-percha master cone thus preventing future leakage in the canal space. Coronal to

this area of retention, the cavity walls are flared whereas the degree of flare depends on the filling technique to be used. Preparing the retention form is done by using files or reamers in a reaming action (rotation).

* ***Extension for prevention:*** this last principle reflects the necessity for extension of the preparation throughout the entire length and breadth to ensure prevention of future problems. This is performed by adjusting the proper working length and planing all the canal walls circumferentially with hand or rotary tools.

LIMITATIONS

In the past, we have been thinking vertically; many students were taught that the first concern in root canal preparation was "working length". We understand now that the critical issue is three dimensionality. Pulp space is a very difficult environment to work. Intracanal instruments (files) are designed to enlarge a straight, uniform, slightly tapered space, which is not the case in root canals. Also files loose their flexibility by increasing their sizes and diameter meanwhile we have to widen root canals for cleaning and filling procedures.

Knowledge of pulp space morphology shows that this space offers different levels of difficulty due to its complex anatomy. This complex anatomy is reflected by:

- Pulp spaces which are much wider in the bucco-lingual dimension than in mesio-distal dimension.
- Cross-sections of root canals which are rarely round along the entire length of the canal but rather oval, ovoid, elleptical, kidney-shaped and C- shaped.
- Root canals which exist in different types reflecting the presence of extracanals as second canal in mandibular incisors or second mesiobuccal canal in maxillary molars Fig. (1).
- Root canals might also exhibit lateral or accessory canals along their entire length or in the furcation area.
  * All root canals show a degree of curvature, which might be in one plane, or curvatures at different planes.
  * The apical foramen may open at the root apex in a centric position or may open in any of the four (buccal-palatal-mesial-distal) surfaces of the root.

N.B.: Our main examination and evaluation tool (endodontists third eye), which is the radiographic examination, may be very deceiving since it offers a two-dimentional image for a three-dimentional space.

Root canal configurations:

I-Root canal classes:

Class I: Straight mature canals.

Class II: Curved mature canals, in which the curve may range from gradual, moderate to severe , dilacerated (near the right angle) and the Bayonet or the double curve in which the canal starts to curve in one direction then turns to a second plane ,usually it is popularly found in maxillary second premolars.

Class III- Immature canals: Canals with wide opened apices;two stages may be observed.

A- The Blunder Buss (old type of guns) canals seen in the early stage of root development where the canal diverge in an apical direction.

B- The tubular canal in which the walls are parallel with no apical constriction.

These conditions are usually met with in cases where traumatic injuries or pulp death have caused cessation of root growth before the root dentin fills in, tapers and constricts the canal lumen.

II-Root canal types: Fig (1)

Type I: One canal with one orifice and one apical foramen.

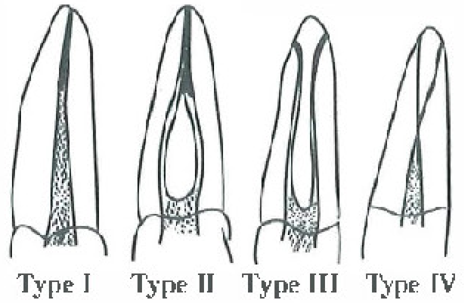


Fig. 1. Different types of root canals showing the possibility of presence of more than one canal in the same root

Type II: Two canal orifices that join into one with one portal of exit (apical foramen).

Type III: Two separate canals with two orifices and two apical foramina.

Type IV: One canal with one orifice that divides apically into two separate apical canals with two apical foramina; this canal type is often encountered in mandibular second premolars.

Instrumentation Procedures

Intra-coronal preparation (access preparation)

Tooth *(working)* length determination

Pulp extirpation

Intra-radicular preparation (cleaning and shaping)

Intra-coronal preparation

A proper access preparation is mandatory prior to canal instrumentation. Straight-line access allows files to be introduced without binding through the pulp chamber and into the canal. Endodontic access cavity should facilitate visual inspection of the pulp space, direct access to the canal orifices,complete control over the enlarging instruments and maximum convenience during the filling phase.

Tooth length determination

Prior to cleaning and shaping of the root canal, the length of the root canal should be accurately measured. This length is measured from a point on the tooth's coronal surface that is within the clinician's field of view and goes apical reaching the apical constriction, which is 0.5-1 mm short of the radiographic apex. The apical constriction is the narrowest point of the canal beyond which the canal widens and develops a broad vascular supply. Therefore, from a biologic and mechanical perspectives the constriction is the most rational point to end the canal preparation.

Determination of the length of the canal can be done either by the **radiographic technique** (Ingle's method) or by **electronic devices** for tooth length measurement (apex locators).

Radiographic method (Ingle's method):

The radiographic technique is considered the most-widely used method. Based on the length of the tooth on the preoperative radiograph and the average tooth length, a pre-measured file is inserted inside the canal. The firmly-attached rubber stopper on the file should be resting on a sound reference point e.g. cusp tip, incisal or canine tip. A radiograph with the file inside the canal is exposed, processed and examined. Working length should be 0.5-1 mm from the root apex. Adjust the length of the file according to the tooth length radiograph.

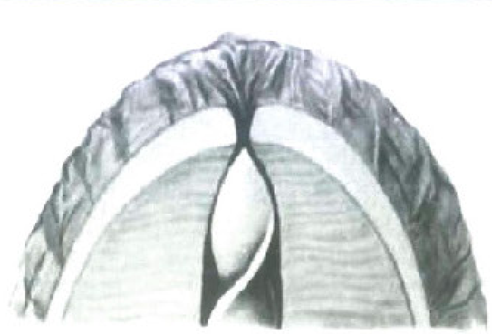


Fig. 2. Cleaning and shaping should be terminated at the apical constriction (working length) which is 0.5-1 mm short of the tooth length

Plastic or rubber stoppers may be square shaped, triangular or pointed (directional)to mark the direction of the canal curve during instrumentation.

Electronic method (Apex locators):

The idea behind these devices depends on the resistance of different tissues to electricity. Oral soft tissues conduct electricity easily, while hard tissues act as an insulator. All apex locators in the market have two electrodes; one touches the patient's oral mucosa, while the second is connected to a file and introduced inside the canal. By passing the file inside the canal, a very small current exists between the two electrodes i.e. a very high resistance exists. This electrical resistance is very high as the file enters the enamel and dentin and decreases as the instrument moves down the canal and, finally, dropping as the file approaches the periapical tissues. Digital reading, light or sound are the indicators for different devices when reaching the end of the canal.

Old types of electronic apex locators were affected by the presence of electrolytes ,blood or saliva inside the canals, whereas recent types that depend on the electric *impedance(**difference in electric resistance between the cervical and apical dentin**)* are said to be more accurate and work efficiently in the presence of electrolytes, hypochlorite, blood and saliva.

Electronic apexlocators have been tested for accuracy against radiographic technique and both were found to be 80-90% accurate. However, radiographs supply the clinician with important data about canal curvatures, number and the condition of the surrounding soft and hard tissues.

Modern devices, such as the radiovisiograph (RVG)supplied with a sterilizable intraoral sensor, allows the operator to utilize less dosage of x-rays (less hazards) and instantly view the image on a large computer monitor where it can be magnified, enhanced and stored.

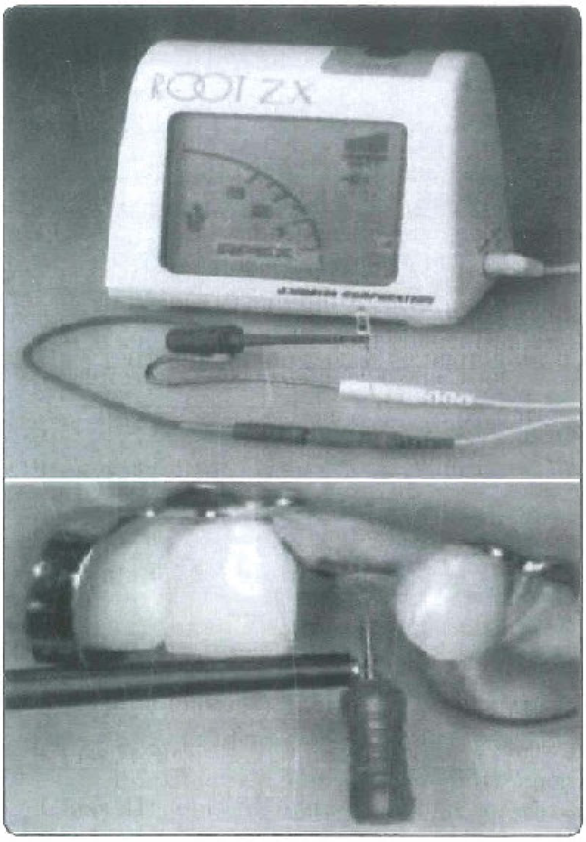


Fig. 3. Electronic measurement of tooth length (apex locator)

Improper tooth length determination will complicate the outcome of the treatment leading to failure of the case. This complication is reflected by either:

(i) ***Internal transportation:*** a condition in which the canal will be prepared short of its real length leading to improper cleaning, persistent infection,ledge formation with subsequent under-filling ending with failure. This error results from short working length determination and is also termed vertical under-extention.

(ii) ***External transportation:*** a condition in which enlarging instruments are extended outside the canal, irritating the surrounding tissues. This situation leads to severe postoperative pain, persistent acute or chronic inflammation with subsequent over-filling ending by failure

of the case. This complication results from over-estimating the working length and is termed vertical over extention and results in a poor apical seal since the apical anatomical barrier against which condensation is made is destroyed.

Pulp extirpation

Pulp extirpation is the complete removal of the pulp tissue from the pulp chamber and the root canal(s) Initial extirpation is performed using nerve broaches (barbed broaches) in large-sized canals and files in small sized-canals. However, complete removal of pulp tissue is not accomplished until working length is established and considerable canal preparation has been done.

Root canal irrigants

Before,during and after the course of cleaning and shaping, root canals should be washed out or irrigated with a solution capable of disinfecting them and dissolving organic matter.Although the major function of the irrigant is to flush debris from the canal,the irrigant should have additional properties that aid in cleaning and shaping.

The instruments can reach only 75% - 80% of the interior of the pulp space

Properties of ideal irrigant

1- Tissue and debris solvent: The irrigant should have the ability to dissolve tissues either vital, necrotic or chemically fixed.

2- Lubricant: The irrigant should have a lubricating action to facilitate sliding of the instruments along the canal walls.

The most important property

3- Antibacterial action: Ideal irrigants should have a bactericidal action against aerobic, anaerobic organisms and bacterial spores.

4- Removal of smear layer (if desirable): The smear layer is a microcrystalline layer of cutting debris covering the canal walls after canal preparation and its removal may aid in a better bonding between the sealer and canal walls.

5- Low toxicity: An ideal irrigant should have minimal or no toxic effect on the periapical tissues.

6- Availability, reasonable cost and adequate shelf life.

Types of irrigants:

Many types of solutions have been used,from distilled water to concentrated acids.

1- Sodium hypochlorite (NaOCl)

- The most popular and advocated irrigant is sodium hypochlorite (Clorox). The full concentration of sodium hypochlorite (5.25%) may be used, however, it is recommended to be diluted by equal amount of water to have a concentration of 2.5%, which decreases its toxicity, while it still retains its action.
- Sodium hypochlorite is an excellent tissue solvent where its action maybe increased by warming the solution, however, warming the solution affects its stability.
- Combining solutions of NaOCl and hydrogen peroxide causes foaming action for better removal of debris; however, this combination inhibit the antibacterial action of both irrigants.
- Alternate use of NaOCl and EDTA is capable of removing the smear layer.

2- Chelating agents:

- The most common chelating agent used as an irrigant is ethylene diamine tetraacetic acid (EDTA). This irrigant has an excellent antibacterial action with no tissue solvent action.
- RC-Prep is a paste composed of EDTA and urea peroxide. This paste,when used with NaOCl is capable of removing the smear layer and producing bubbling action due to interaction of urea peroxide and NaOCl. This bubbling helps loosening and floating of dentinal debris.

. Cause the Root is tortuous, curved roots, canals that join, divide

RCT is all about Control: control the patient, instrument, technique ***

3- Hydrogen peroxide (3%):

Earlier it was a very popular irrigant due its effervescence action, which is capable of removing loose debris from the inside of the canal. In addition, the release of nascent oxygen works against anaerobic microorganisms. Now,it is not so popularly used because of the fear that forcing it into the periapex results in release of oxygen that will be trapped apically causing severe postoperative pain and emphysema.

4- Quaternary ammonium compounds:

The most popular irrigant of this group is the 9-amino acridine. This irrigant is an antiseptic with low toxicity with no tissue dissolving property.

5- Chlorohexidine Gluconate (0.2%):

This chemical was shown to have antibacterial action comparable to that of NaOCl but, again, it does not have tissue solvent action.

6- **Antibiotics** have been tried as irrigating solutions with success in cases with long standing infections and patients who cannot tolerate orally-administered antibiotics. The most commonly used antibiotics are metronidazole and tetracycline.

7- **MTAD** which is a mixture of tetracycline, an acid and a cleaning detergent.

The irrigant can penetrate 3-5 mm after the needle tip

Method of irrigation:

The technique of irrigation is simple by using a plastic syringe and bending the needle to allow easier insertion inside the canal. It is strongly recommended that the needle lies passively inside the canal, as forceful irrigation can push the irrigant into the periapical tissues leading to severe complications.

Goldman developed an irrigating needle which have a sealed end with ten side perforations along its length for side delivery of the irrigant.

Ultrasonic irrigation is considered the most effective method of root canal irrigation where the vibrational motion of the files inside the canal moves the irrigant in a vortex like motion cleaning areas which cannot be reached by the files. In addition, this motion causes warming of the irrigant, thus, increasing its action.

A recent adjunct for cleaning and shaping is the Irrivac system which is a combined irrigation needle with a suction tip for delivery of the irrigant and its rapid suction at the same time.

Recently, a sonic device (ENDO-ACTIVATOR) was introduced utilizing a flexible nylon fiber with gauges 20/25, and 30 to vibrate passively inside the canal activating the irrigant,warming it and delivering it to inaccessible areas.

In summary, it appears that NaOCl 2.5% provides both excellent antimicrobial and tissue solvent actions putting into consideration that the proper technique of irrigation is followed to avoid its toxic properties. If it is desired to remove the smear layer before obturation, EDTA should be used in combination with NaOCl.

It should also be noted that debridement by irrigation is a function of volume,so at least two ml should be delivered each time of irrigation to be effective.

INTRACANAL MEDICATION;

Endodontics is one of the dental specialities that uses antimicrobials as an adjunct in infection control in treatment of nonvital as well as in vital cases in medically-compromised patients.

Antimicrobials may be divided into chemotherapeutics (to be discussed separately) which are specific in action and antiseptics, which are non specific in action.

Antiseptics may be classified into:

1- *Alcohols; ethyl and isopropyl alcohols are used prior to obturation to dry the canal and remove the water content for better sealer adhesion.*

II- Phenolic compounds; phenol, camphoratedphenol, camphorated monochlorophenol (CMCP)and formocresol {aldahyde ester, 19% formaldahyde, cresol 35%, water and glycerine 46%} are localy acting antiseptics that work by denaturation and clumping of cell wall proteins, thus, altering the functions of bacterial cell wall causing bacterial death. They are vapour-forming chemicals with different grades of spreading and dentinal penetration being maximum with formocresol followed by the CMCP and the least penetrating are the camphorated phenol and the phenol and, thus, they are the least potent and least irritant. Yet all phenolics are considered irritants and potentially carcinogenic which became a controversial issue in the past few years.

III- Halogens; Iodine potasium iodide 2, 5% were also found very effective against the root canal flora without the periapical irritating quality of the phenolic derivatives so they are highly recommended as root canal medications, hypochlorites as the sodium salt 0.5-5.25% have been discussed with root canal irrigants.

IV- Calcium hydroxide; great interest is being directed towards calcium hydroxide in endodontics owing to its antimicrobial action, specially against the bacteriods of endodontic concern and its tissue dissolving action which encourages its use as intracanal medication and irrigant; also its osteogenic effect, which encouraged its formulation. as root canal sealers.

V- Antibiotics; have been tried as intracanal medications but the fear of developing bacterial resistance, jeopardizing the systemic use, have led to the retreat of its local use.

VI- Steroid/antibiotics; the local use of steroids as intra-canal medication was tried with successful results, however, the fear of lowering the immunity in an already infected area has led to a combination of steroids to lower the inflammation and antibiotics to control the infection {Leddermix}.

Intra-radicular preparation

It should be clarified that in discussing intraradicular preparation, two terms should be clear:

I- Basic instrumentation motions, which is the type and direction of motion the operator performs while holding the tool and working the canal space, i.e. vertical filing, rotation clockwise, counter clockwise and so on.

II- The preparation techniques, which is the sequence and steps taken for preparing the canal, i.e. apical - coronal, coronal -apical or combined.

Basic instrumentation motions (maneuvers)

Cleaning and shaping of the root canal is performed by endodontic instruments (e.g. files) being moved against the dentin walls either in a linear motion (up and down) or rotation motion. These motions are being referred to as "***BASIC INSTRUMENTATION MOTIONS***" *Fig. (4)*

Filing motion: This is a linear motion in the form of push and pull action. It is the most efficient motion in cutting dentin. All types of files can be used with this motion, however, the H-file is considered the best as it has the highest cutting efficiency. This motion is recommended for enlarging the coronal 2/3 of the canal (circumferential filing) Fig. (4A).

Reaming motion: This is a rotation motion. The term ream indicates clockwise or right-hand rotation of the instrument. It is assumed that this motion produces round cross-section of the root canal, however, chances of the instrument to fracture is increased. Reamers and K-files are suitable for this motion, and they are intended for use in the apical third to prepare circular cross sections to best fit the circular cross sections of the master gutta percha cone Fig. (4B).

Turn and pull: This is a combination of reaming and filing where the instrument is inserted with a quarter-turn clockwise (reaming) motion then the file is subsequently withdrawn (filing) Fig. (4 C).

Watch winding motion: This is a rotation motion. The instrument is being inserted in the canal with a gentle clockwise/counterclockwise (30-60 degree) motion (right and left). Reamers and K-files are suitable for this motion Fig.(4D).

Stress relieve stress

Balanced force: It is a rotation motion. It is identical to the watch winding in which the instrument is rotated right and left inside the canal until reaching the desired length. Now, the instrument is rotated to the left (counter clockwise). This left rotation attempts to drive it out of the canal so, the clinician must apply apical pressure to prevent outward movement A to obtain cutting. Simultaneous apical pressure and counter-clockwise rotation of the file strikes a balance between the tooth structure and instrument. This balance keeps the instrument centralized inside the canal,thus,minimizing the chances for canal transportation. This counter-clockwise rotation that cuts dentin tends to push the dentin apically away from the file,so a clockwise turn is made to load the debris on the file and pull it away. Flex-R-file (modified K-file) is the instrument of choice to be used with this motion due to its triangular cross section (less metal mass = more flexibility) and for its non-cutting tip Fig. (4 E).

N.B.:All rotation motions are recommended to be used in enlarging the apical 1/3 of the canal due to their ability to offer a round preparation.

Clockwise : engage dentin
Counter clockwise : Cut dentin

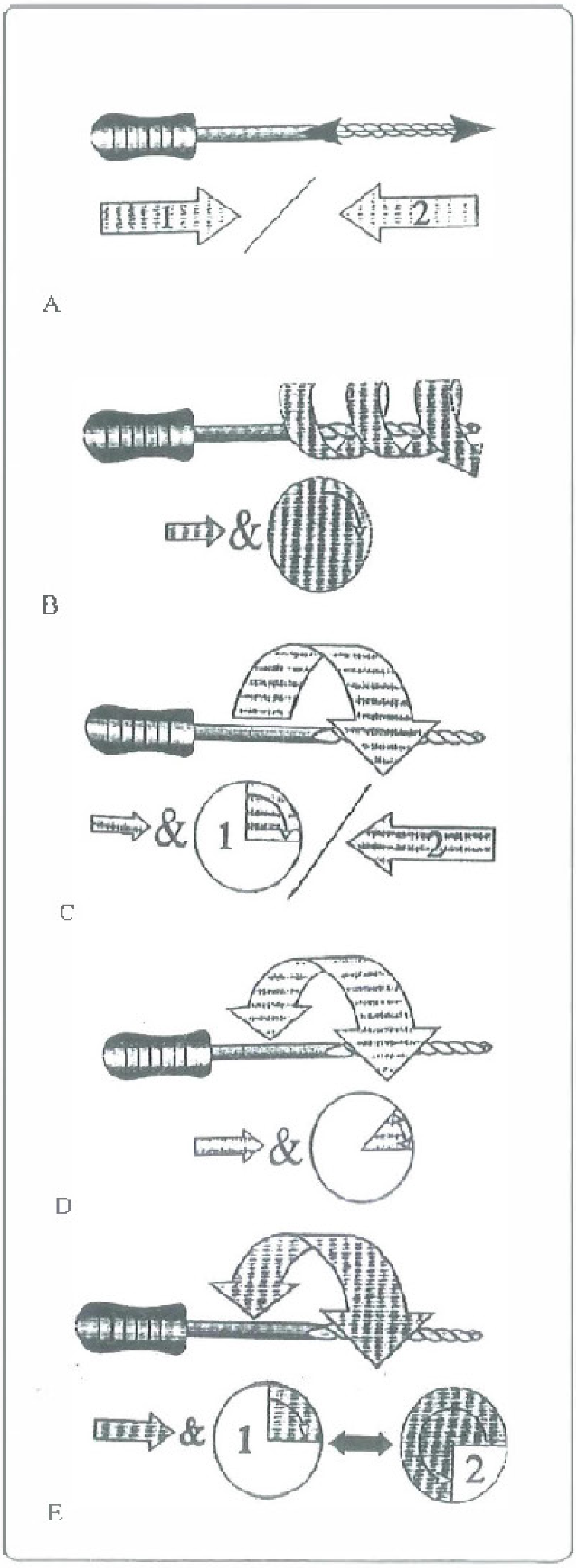


Fig. 4. Basic instrumentation motions; A: filing, B: reaming, C: turn and pull, D: watch winding, E: balanced force

Techniques for Instrumentation (approach)

Over the years, two different approaches to root canal cleaning and shaping have emerged: the ***apical-coronal and, the recent concept,coronal-apical***. The apical-coronal starts enlarging the apical third first followed by flaring the coronal two thirds. This approach is exemplified by the apical stop technique (Basic) and the step back technique. The coronal apical approach starts flaring the coronal two thirds first (preflare) followed by apical preparation as a final step; this approach may be exemplified by the crown-down pressureless technique. A **third approach** is recently introduced which is a hybrid technique where the coronal two-thirds are preflared at first then the working length determined and the apical third is stepped-back, this was termed the **step-down technique**. Anyone or more of the previously-mentioned basic instrumentation motions can be used with any of these techniques.

I- THE BASIC TECHNIQUE, APICAL STOP, (CIRCUMFERENTIAL FILING):

In this technique, the working length is determined first and starting with the first file to bind at the working length (INITIAL FILE). The file is used in a filing motion along the whole circumference of the canal to plane all the surfaces till the file feels loose inside the canal. The canal is irrigated and the next file is used along the full length circumferentially till it becomes loose,and so on the sequence is repeated. Enlarging and washing the canal for at least three to four successive sizes larger than the initial size, are performed till reaching the largest file used at the full length, now termed the MASTER APICAL FILE, according to which ,the master guttapercha point is selected. The main goal is to enlarge the canal along the whole length with establishing a definite apical stop, while taking all file sizes to the full length regardless of the canal anatomy or the instrument flexibility.

[Initial file + 3-4 file sizes along the whole working length, irrigation in between each file + final circumferential filing]

This technique has the advantage of planing the whole circumference of the canal and its simplicity to be used by unexperienced operators in straight canals. However, it was proven that this technique is quiet damaging when used in curved canals, as increasing the size of the instruments decreases its flexibility (more mass=less flexibility) with subsequent indiscriminate increase in the stresses applied by the files on the canal walls, leading to areas of increased cutting (critical zones)and areas of less cutting (safe zones) and, accordingly, uneven planing and cleaning of the canal dentin with design errors in preparations as PEAR SHAPED, HOURGLASS (INGLE) and ZIPPING (WEINE) of the apical third of the canal.

Did NOT Respect the Canal Morphology

Modification of this technique was developed which advises the operator to pull or drag the files in an anticurvature direction to put more pressure and cut more in the safe zones and avoid the critical zones. This was termed

ANTICURVATURE FILING TECHNIQUE.

THESE ERRORS CAUSED BY THE BASIC TECHNIQUE LED TO THE DEVELOPMENT OF THE STEP-BACK TECHNIQUE.

STEP-BACK TECHNIQUE (Telescopic preparation) Fig. (5)

The step-back technique was first described by Clem (1969) and became popular as it creates smoother flow and a more tapered preparation.

This technique has the advantage of respecting the canal anatomy and the instrument flexibility where only small and flexible instruments are taken to the full working length, while larger stiffer instruments are stepped back and used in more coronal areas away from the maximum curvature of the canal.

Cleaning and shaping of the root canal by the step-back technique include three phases. In phase one, the motion used is a rotation motion (reaming, watch winding or turn and

Choosing ...
MAF depends on → Type of files material

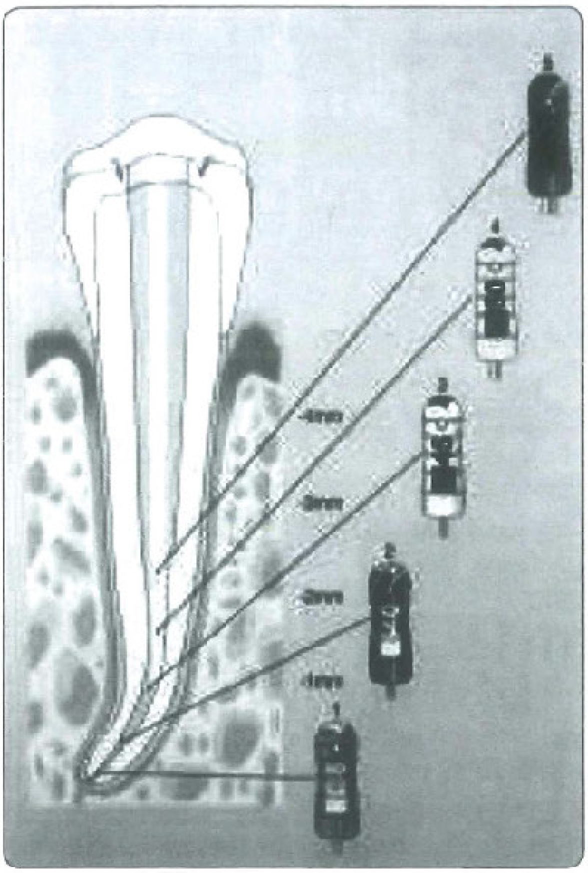


Fig. 5. The step-back preparation (Phase I, II & III)

pull motion) and its aim is to prepare the apical portion of the canal (apical preparation phase) starting by the initial file till reaching the MAF. In phase two, the canal is enlarged with larger files in a step-back fashion;that is larger files move 1mm backward in a coronal direction in a series of steps. In phase three, the motion used is the filing motion around the circumference of the canal (circumferential filing). The aim of phase two is to enlarge and flare the coronal two-thirds of the canal (flaring phase). The technique is described as follow:

Phase one (apical preparation)

- Based on the tooth length determination, select the ***INITIAL FILE*** to start your cleaning and shaping. The initial file should reach the working length with slight resistance(BINDING) at the apical third.
- The initial file is inserted inside the canal to the full working length using a watch winding motion (back & forth motion).
- When reaching the full working length, the initial file is given a quarter-turn motion in a clockwise direction then withdrawn outward ***(turn and pull motion).***
- This action is repeated until the file is totally loose inside the canal. Make sure that you irrigate frequently during preparation.
- This procedure is repeated until the apical area is prepared at least three sizes larger than the initial file. The largest file reaching the full working length is what we call ***"MASTER APICAL FILE"*** (MAF). Remember: Always keep the canal flooded with the irrigant and never force an instrument inside the canal.

Phase two (stepping back)

- The next step would be to step backward using the larger size files while shortening the working length to obtain a flared preparation.
- This step-back preparation is done by sequentially inserting files larger than the MAF in a passive manner i.e. no pressure is applied to the file handle to push it deeper inside the canal. This size will mostly stop short of the working length. Move the file in a cicumferential filing motion to smoothen the dentin walls.
- Irrigate the canal and go back again to the MAF placing it to the full working length to carry the collected debris outside the canal to avoid canal blockage and smoothen the walls. This is what we call ***"RECAPITULATION".***
    * Step backward again and recapitulate until the canal appears to be tunneling out smoothly; now the apical third is prepared and flared.

* Neglecting this phase would lead to formation of a series of ledges simulating an opened telescope and, hence, it was called the telescopic preparation

ie irrigant reaches the foramen at the end only

Phase three (flaring)

The working length is shortened by the amount of the apical third and the coronal thirds are now flared by rotary tools or by H-FILES in a circumferential filing technique.

MODIFIED STEP- BACK TECHNIQUE:

This technique may be used in less curved or almost straight canals. It simply envolves establishing the proper working length. Start to enlarge the canal with sequentially larger files for the preparation of an apical seat with the MASTER APICAL FILE of an appropriate size using a reaming action to prepare a circular cross section at the apical third. The working length is then shortened by 3-5 mms to leave what is known as the retention form with its circular cross section, then the rest of the canal is enlarged using either a rotary tool like the Gates Glidden drills, or using 1 file in a circumferential filing manner. The amount of canal flare depends on the obturation technique to follow and the need for using posts.

THE CROWN- DOWN TECHNIQUE

Practitioners were pleased with the results of the step-back technique, yet it was found to be a lengthy boaring procedure, and the evolution of the modern rotary tools together with the need to improve the quality of the preparation and to shorten the time of treatment, have led to the development of the Crown Down pressureless technique by Marshal.

This technique depends on canal preflaring using either a rotary tool like the Gates Glidden drills or an H-file in a circumferential filing technique, extending about 16 mm inside the root or at least the cervical and middle thirds of the canal.

The second step is to penetrate the canal with a large file to the apical third with absolutely no apical pressure i.e. file # 35 or 40 depending on the size of the canal

This is followed by using sequentially smaller files(30-25-20-15) down the canal in what is known as waves of instrumentation advancing from the coronal to the apical direction. When the files reach 2-3 mm shorter of the suggested average length (determined by the pre-operative radiograph), which is termed the Provisional working length, a confirmatory working length radiograph is made for an accurate working length determination.

The final step is to instrument the canal starting by large files and advancing apically using sequentially smaller files with no apical pressure. The second wave of instrumentation would be (40-35-30-25), the third would be(45-40-35-30).These waves are repeated till adequate apical preparation is reached and a MASTER APICAL file size is determined.

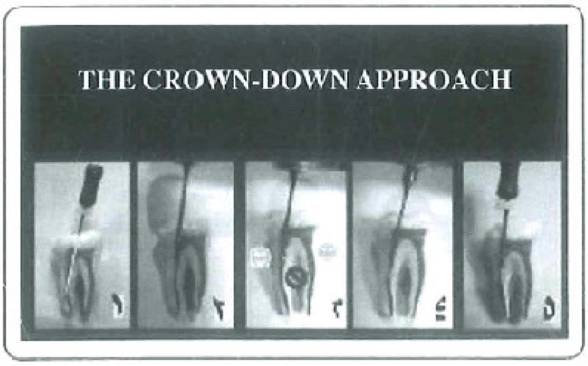
ADVANTAGES OF THE CROWN-DOWN CONCEPT (CANAL PREFLARE) EXAM

1- Gross debridment of two thirds of the canal contaminants and so less microorganizms and debris are pushed apically and, hence, less liability to flare ups and post-operative pain.

2- Eliminates coronal and middle thirds dentin resistance to the files so improves tactile sensation since the first resistance encountered is the apical constriction.

3- Less stresses on the instruments results in less stresses on canal dentin and, hence, less liable to ledge or perforate the canal; also, less likelihood to fracture the instrument.

4- Since coronal resistance is eliminated in the straight part of the canal, the operator can better negotiate the apical curve with less stresses on the instrument.



5 Deeper penetration of the irrigation needles means deeper irrigation effect in the apical region , with formation of a large reservoir for the irrigant.

6- Preflaring with rotary tools shortens the preparation time. so less fatigue to the patient and the operator occurs.

ALTHOUGH THE CROWN-DOWN CONCEPT GAINED POPULARITY FOR ITS BENEFITS, IT WAS FOUND TO BE TIME CONSUMING SO A HYBRID TECHNIQUE WAS DEVELOPED WHICH IS TERMED:

THE STEP-DOWN TECHNIQUE.

This technique depends on preflaring the canal from a coronal direction using engine driven instruments from the smaller to the larger (depending on the canal size). The working length is then properly established,and the apical third is prepared in a step- back manner.

A small patency file is advanced to check for the patency and direction of the canal. The smallest gates size # 1,2 or 3 may be used to reach the apical third or at least the mid root as dictated by the canal anatomy and type of curve(in curved canals). This is followed by irrigation then the next gates size (# 2,3,or 4) may be used more cervically. Again the canal is irrigated,checked for patency and the larger drills used at the cervical third and canal orifice.

The apical constriction may now be felt by tactile sensation and the proper working length radiograph is now made. The initial file is used with a watch-wind motion and sequentially larger files are used to reach the MASTER APICAL FILE. The apical third may now be flared by step-back or modified step-back techniques.

IT WOULD NOT BE POSSIBLE TO CONCLUDE THE CLEANING AND SHAPING TECHNIQUES WITHOUT DISCUSSING

THE BALANCED FORCE TECHNIQUE.

Although it was introduced by James Roane as a technique of preparation,it maybe considered a file maneuver than a technique of preparation.

STEP I: The file (Flex-R) is introduced inside the canal using a clockwise rotation to drag the file passively down the canal to the working length.

STEP II: At the desired working length,the file is rotated in a counter-clockwise direction with a slight apical pressure as rotating the file in a counter clock-wise direction tends to unscrew the file back the canal in a coronal direction. It is during the counter rotation,the dentinal cut is made. This counterclockwise rotation is said (by Roane) to balance the tip of the file towards the center of the canal rather than towards the outerside of the curve and, hence, it is found to minimize canal zipping or transportation. The problems with counter clockwise rotation are;

First, the debris are pushed in an apical direction and

Second, the file tend to fracture a brittle fracture (sudden). In a clockwise rotation,when a file is locked,it unwinds then elongates and is reverse twisted then fractures a ductile type of fracture which allows the operator to detect these types of deformation and discard the instrument in the proper time before fracture. Whereas in the counter clock wise rotation the locked instrument is over twisted, shortened and breaks instantly in a brittle type of fracture because of the fore mentioned reasons.

STEP III: The file is again rotated in a clockwise (one full turn)direction to load the debris and get it out of the canal. This sequence is repeated with all the larger files sequentially till reaching the proper size of THE MASTER APICAL FILE; the coronal flare may be made by hand or rotary tools.

ALTERNATIVE TECHNIQUES FOR CLEANING AND SHAPING

Other approaches to canal preparation have been proposed. Because conventional preparation with hand instruments is somewhat difficult and time consuming, engine-driven instruments have been suggested. Two types of motions are utilized either rotational motion or vibrational motion.

I- *Engine-driven instruments utilizing rotational motion:*

These include large variety of special handpieces that rotate back/forth or in a quarter-turn or even up and down few millimeters. Tips mounted on these handpieces are files or reamers with latches instead of handles. Rotational engine-driven instruments were not widely accepted in the past due to problems that appeared when using them, which included:

1- Less effective in canal debridement.
2- More tendency for canal packing with dentin debris.
3- More tendency for ledges and perforations.
4- More tendency for canal straightening.
5- More tendency for instrument breakage
6- Loss of operator sense of canal topography.

However, the new generation of engine-driven instruments were greatly modified and nowadays, are comparable to hand instrumentation techniques. Modifications included:

1st- Modification in the handpiece:

- High torque
- Very low speed (300-1200 RPM)
- Steady rotation

2nd-Modification in the cutting tool:

- Nickel-titanium files (flexible)
- Increased taper

II- *Engine-driven instruments utilizing vibrational motion: (Sonics & ultrasonics)*

The utilization of vibrational motion in endodontics was first introduced more than twenty years ago by Martin. The power source (electromagnetic or piezoelectric) is transferred to a special insert that hold a special instrument similar to a file. When the file is energized in a canal flooded with irrigant, the fluid motion helps loosening debris with better flushing of canal contents together with file scraping against the dentin wall.

The results of the studies have shown that canal enlargement using sonics and ultrasonics may not be efficient as hand instrumentation and is even less effective in small curved canals. However, flushing and disinfection appear to be very effective with the sonics or ultrasonics.

	SONICS	ULTRASONICS
SPEED RANGE	<20,000 HERTZ	20 - 35 KILOHERTZ
POWER SOURCE	COMPRESSED AIR	PIEZO-ELECTRIC
TOOLS	RISPI & SHAPER (R.TYPE)	K-TYPE & DIAMOND
IRRIGANT	WATER	Na-HYPOCHLORITE
BRAND	MM 5000	ENDOSTAR

GUIDELINES FOR INSTRUMENTATION OF DIFFICULT CANALS

The ideal canal enlargement would be the one that enlarges the canal while retaining the canal pre-operative shape. In a straight large canal, this rule is easy to apply, but studies have shown that straight canals are the exception and the majority of root canals show a degree of curvature.

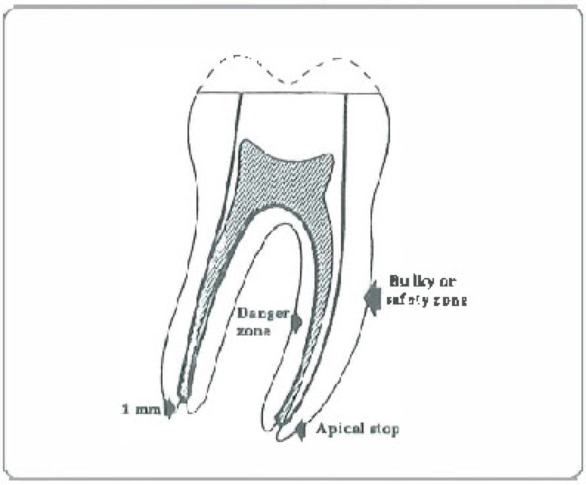


Fig. 7 The distribution of the restoring forces along the length of the instrument

When a file is inserted in a curved canal, elastic forces develop inside the instrument. These forces attempt to return the instrument to its original shape, hence, it is called **"Restoring forces"**. These forces act on the canal wall during preparation and influence the amount of dentin cut by the instrument. The restoring force is not equally divided along the length of the instrument being maximum at the instrument tip Fig. (7). This phenomenon is responsible for most of the procedural errors, which occur during canal enlargement.

These guidelines should always be remembered regardless of the technique of instrumentation used.

1- Always work files in a canal filled with **irrigant.**

2 Never **skip** intermediate instrument sizes during preparation.

3- Never **force** files inside the canal to avoid instrument breakage or packing of debris in the apical region of the canal.

4- **Precurving** of instruments: a precurved file is a valuable tool for feeling canal passages and for moving around calcifications and ledges. In addition, a curved file helps alleviate the adverse effects of canal curvature.

5- **Anticurvature filing** concept: this concept describes the action of pulling the files against the outside wall of the canal. This directionally-applied pressure prevents straightening of midroot curvatures, which can lead to strip perforation.

6- **Radicular access:** This procedure is employed nowadays in most instrumentation techniques. It describes enlarging the coronal 1/3 of the canal before initiating the cleaning and shaping. This can be accomplished either by rotary instruments (Gates Glidden drills)Fig. (6) or by circumferential filing using H-files

TERMINATION OF CANAL PREPARATION

How much should the root canal be enlarged? The answer is simple. Canals should be enlarged enough to permit adequate debridement as well as manipulation and control of obturating materials and instruments. It is an interaction between three major factors:

I- Canal anatomy: Curve Curved canals (specially at the apical third) require less widening,as using larger instruments will either damage the canal walls or will fracture.

amount of apical flare depends on

II- Instruments used: Using more flexible designs and materials of construction allows the operator to enlarge the canal in the apical third to larger sizes,i.e. for a severely curved canal, having a regular K-st-st file may allow an apical preparation to size 25. Whereas having a K-flex st-st may allow an apical enlargement to size 30-35, while using one of the new NICKEL TITANIUM instrument systems may allow an apical preparation of the same curve to size 40-45.

amount of coronal flare depends on the: Obturation technique

III The operator skills: Experienced operators with wide range of skills are more able to deal with more complicated cases, whereas less experienced practitioners are better advised to stick to the basic techniques to which they are more trained.

2- Clean dentin
3- Adequate flare for the used obturation technique

Criteria for termination of canal preparation

1- **Debridement:** All walls should feel smooth along the whole length of the canal together with clean yellow dentin debris.
2- **Apical preparation:** An apical stop (apical control zone) should exist. This is tested by the failure of the master apical file to pass beyond the working length when a reasonable apical pressure is applied to it (RESISTANCE FORM).
3- **Adequate taper:** Selected obturating instrument (spreader or plugger) can reach easily to within 1-2 mm of the working length.

PROCEDURAL ERRORS DURING CLEANING AND SHAPING

Iatrogenic changes in root canal during cleaning and shaping do occur especially in narrow curved canals. The majority of these complications occurs as a result of improper control over the preparation instrument. These procedural errors include:

I- Canal blockage

This condition occurs when the operator feels that canal patency is lost during cleaning and shaping.

Diagnosis

- Full working length can not be reached.
- At the area of blockage, the canal feels sticky due to aggregation of debris.

Etiology

- Failure to maintain full working length during preparation.
- Insufficient irrigation.
- Failure to recapitulate during preparation.

Treatment

To solve this situation, the operator should irrigate the canal and start negotiating the canal at full working length using the initial file (smallest file reaching the working length).

Ultrasonic irrigation may be very benificial in stearing back the accumulated debris and facilitate its removal by irrigants. Also the alternate use of hypochlorite/peroxide solutions with the resultant bubbling effect may help removal of the blocking debris.

II- Ledge formation

This condition is noticed when the operator feels that full working length cannot be reached.

Diagnosis

- Loss of working length.
- End of canal feels as a solid wall (non sticky).
- Radiographically, file appears to leave the original path of the canal.

Etiology

- Insufficient irrigation.
- Failure to recapitulate
- Using large-sized instruments in small curved canals.
- Skipping of instrument sizes during preparation.
- Dry filing of root canals.

Treatment

To solve this situation, the operator should irrigate the canal and try to relocate the original canal. This is done by placing a sharp bend, at the last 1-2 mm, of a file #15. This tip is teased along the canal wall opposite to the wall which is expected to have the ledge until the full working length can be re-established. This is followed by filing of the wall which contains the ledge.

III- Perforation

This problem can occur anywhere along the length of the canal.

Diagnosis

- Sudden pain.
- Sudden bleeding in a canal originally dry.

- Radiographically, the file is seen projecting out of the canal when perforation is located in a favourable site to the x-ray beam.
- Insertion of a paper point alongside the perforation will show a red spot (blood) corresponding to the perforation level.

Etiology

- Improper working length (apical perforation).
- Boring through a ledge (side perforation).
- Over-enlargement of small canals leads to longitudinal perforation (strip perforation).

Treatment

- If perforation was apical, re estab lish working length and create a new apical stop by enlarging the master apical file one or two sizes.
- If the perforation was a side perforation, try to relocate the original canal and complete the cleaning procedure. The perforation can then be sealed during canal obturation or an external seal can be per formed surgically.
- Strip perforations are difficult to deal with. Obturate the canal and follow up the case.
- Attempts to induce external calcific barrier by filling the canal with calcium hydroxide may be tried for three to six months and may last up to two years.
- Failing cases may require surgical correction to seal the perforations externally.

IV- Instrument breakage

During instrumentation, a fragment of the instrument can break inside the canal. This fragment blocks the canal, thus preventing routine cleaning and shaping. This condition is diagnosed as follow:

- Sudden loss of working length (canal blocked).
- Loss of a fragment of the instrument.
- Radiographically, the instrument fragment can be seen.

This condition occurs due to:

- Frequent use of the instrument (instruments should be discarded before metal fatigue).
- Using excessive force during instrumentation.
- Failure to inspect the instrument before use.
- Locking the instrument in a dry canal.
- Rotation in a counterclockwise direction.

The prognosis of this condition depends on several factors:

- Location of instrument (apical, middle or coronal).
- Size of the instrument.
- How much cleaning was performed apical to the broken fragment before instrument breakage.
- The nature of the pulp disease (vital or non-vital case).

The best correction of this error is to try to remove this fragment. If impossible, try to bypass it and complete the instrumentation procedure. Ultra-sonics may be of great value in trying to loosen the locked instrument and flush it out with irrigation.

If this is impossible, clean and obturate the canal to the level of the fragment and follow-up the case.

Failing cases may require surgical intervention to retroseal the apical root segment.

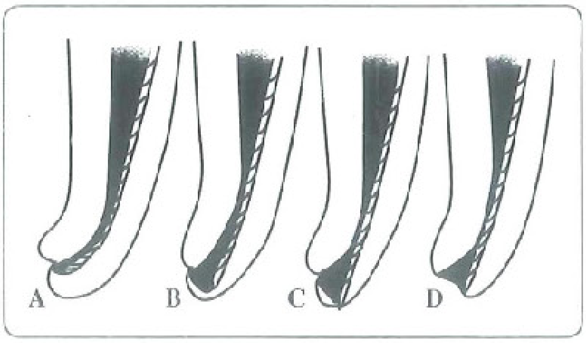


Fig. 8. Different procedural errors during instrumentation of curved root canals

ROTARY INSTRUMENTATION

Rotary and power-driven instruments have always been a dream to practitioners aiming to an effortless, fast and uniform smooth preparations.

In the sixties, the standardized preparation technique appeared to be a simple technique where the filling points match the cutting tools. However evaluating this technique in the Washington study, performed over 3000 cases, proved to cause damage to root canals that were believed to be simple and straight as the maxillary lateral incisors and the palatal roots in maxillary molars which were thought to be easy canals to treat.

The problem was that geometrically irregular and curved canals were instrumented using geometrically very regular instruments which at that time were made of stainless steel alloys that lose flexibility with increasing the instrument's size during the procedure of cleaning and shaping. The findings of the sixties have led to the development of the step-back (telescopic) technique in the seventies where the root canals were instrumented to the master apical file size that will not damage the canal curvature or endure unnecessary stresses which lead to its failure or separation. So, a file will only be used where it is going to function safely. Subsequent sizes are worked back in the canal shortening the working length by small increments in a stepping back fashion, then the body of the canal is flared as a final phase. This technique, though proved to respect the canal anatomy and instrument capabilities, it is time-consuming, causes fatigue to the operator & the patient and requires a huge number of tools to prepare each canal.

At the same time, anatomical studies showed that small canals in the maxillary and mandibular molars, measured between sizes #20- #35 before instrumentation but failed to explain why clinicians couldn't start their preparations with sizes more than #10 or #15, till *"Leeb"* pointed out that endodontic instruments reach the maximum stresses inside the root canals at the *elbow area* which explained why a file size #15 or #20 cannot penetrate a canal size #30 to the full working length and the fact that most instruments separate at or past the elbow area (maximum stress on the tool and canal).

These findings paved the road to *"James Marshall"and"Pappin"* to develop the crown-down approach in 1982 which was a blessing to clinicians, patients and the endodontic instruments.

Along with the crown-down technique, came another gift to endodontic practice which was the introduction of the first nickel titanium hand instrument in 1988. However hand NiTi instruments were very disappointing regarding cutting efficiency which led to a shift in manufacturing from hand NiTito rotary NiTi opening a new era in endodontic canal preparations.

When manufacturers first presented NiTi rotary files with 2%taper, they were weak, spinning inside the root canals and with inadequate contact with canal walls and, thus, had poor cutting efficiency and high fracture rates. So they had to increase rotary NiTi file tapers from 2% to 4% then 6% and now up to 19% which produced stronger files with better canal wall enlargement and higher cutting efficiency.

Compared to hand instrumentation, rotary NiTi preparations may be considered *"a walk by the river"*. However, two problems were associated with the newly-introduced tools: First, was the lack of tactile sensation. This was partially solved by introducing the smart motors that featured an auto-clutch mechanism which, at locked positions, stop rotating and revolve in a counter clockwise direction relieving the instrument from the locking situation and preventing its fracture. Also these motors were equipped with built-in apex locators to determine the proper working lengths.

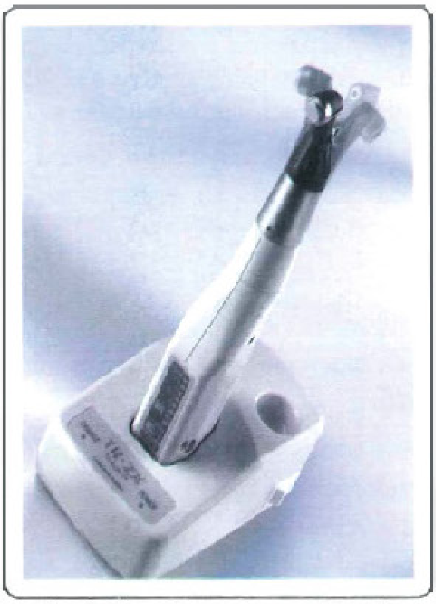


Fig. 9. Smart Rotary motor (RT-ZX)

NiTi alloys are known to be super-elastic alloys unless subject to sudden change in rotational speed or torque where it undergoes internal phase transformation into a brittle phase (martinsitic phase). Which is a very brittle phase showing sudden and immediate instrument fracture(disarticulation).

This is the reason why rotary NiTi files could not be operated in regular electric motors that may change the speed and torque during pressing their foot pedals to accelerate or decelerate. Therefore, Smart motors are a prerequisite for rotary NiTi instrumentation.

The other problem associated with NiTi files is cyclic fatigue and torsional failure due to alternate compression and tension during rotation along curved canals leading to sudden brittle fracture with no or little signs of deformation. This remains the major risk during working with rotary NiTi tools.

Rotary endodontic instruments went through alot of modifications and generations to reach the success enjoyed by the present tools.

Starting with first generation, the Profile system was presented with three tapers: 4%,6% and 5-8% to work in the apical, middle, and coronal thirds respectively.

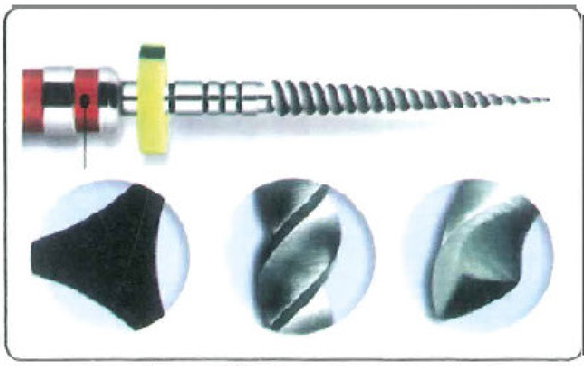


Fig. 10. Profile system design

The system was presented with a torque control handpiece to operate with regular electric motors which led to high fracture rates due to change in speed using the motor pedal control.

Also, a second problem with the Profile system was the sucking-in effect due to the threaded design and the uniformity of the instruments and, finally, the system didn't enjoy high popularity because of the large number of files up to 6 sizes per taper *i.e.*18 instruments employing 3 tapers for selection.

The same manufacturer (DentSply), however corrected all the drawbacks in their first generation (Profile) and came out with a state of the art:

ProTaper system

Which came with a Smart motor that is programmed for a fixed speed and torque, an auto-clutch mechanism with an auto-reverse feature and, lately, with a built-in apex locator. The system is composed of six instruments: 3 shapers and 3 finishers.

1- **The Sx:**

- Which is a short instrument with *14mm of* blades equivalent to size#19 ISO and tapered *19%*.
- Used for coronal 2/3 flaring before measuring the working length.
- The instrument is short tool *19mm* and is not identified with a colored ring like the other instruments.

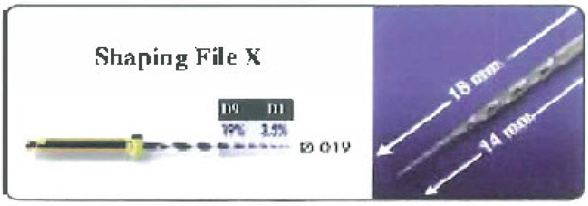


Fig. 11. SX file

2- **The shaping S1:**

- Which is equivalent to size *#1 7* ISO and tapered *2%* at the tip till reaching *11%* at *D16*.
- The instrument is color coded ***purple*** and intended to be used first in the coronal 2/3 then to the full length after working length determination.

3- **The shaping S2:**

- Which is equivalent to size *#20* ISO and tapered *4%* at the tip reaching *11.5%* taper at *D16*. The instrument is color coded *white*.
- Also used to flare the coronal 2/3 first then to the full working length after WL determination.
- The second set of files is called the finishing files

4- F1:

- Is equivalent to size *#20* ISO and tapered *7%* at the tip with a taper *5.5%* at *D16*.
- It is color coded yellow.
- Intended to finish canals in severely-curved roots.

5- **F2:**

- Equivalent to size *#25* ISO and tapered *8%* at the tip reaching *5.5% taper* at *D16*.
- The instrument is color-coded ***red*** and intended to finish average to severely curved canals.

6- **F3:**

- This instrument is equivalent to size *#30 ISO*, tapered *9%* at the tip reaching *5%* at *D16*.
- It is color-coded ***blue*** **and**
- Intended to finish gently-curved and large canals.
- Lately, two more finishing files were added: F4 and F5 equivalent to size *#40*, *#50* and tapered *6%* and *5%*respectively to finish and enlarge canals of premolars and anterior teeth.
- All the files are used between 250-350 RPM with torque values between 2 4N/cm²; the larger the size, the greater the torque used.
- All the files except the Sx, have black marks for WL identification at 18,19, 20, 22 mms for ease of monitoring the WL during rotation.

Looking for simplicity, a new rotary system has been introduced consisting of only 3 files.

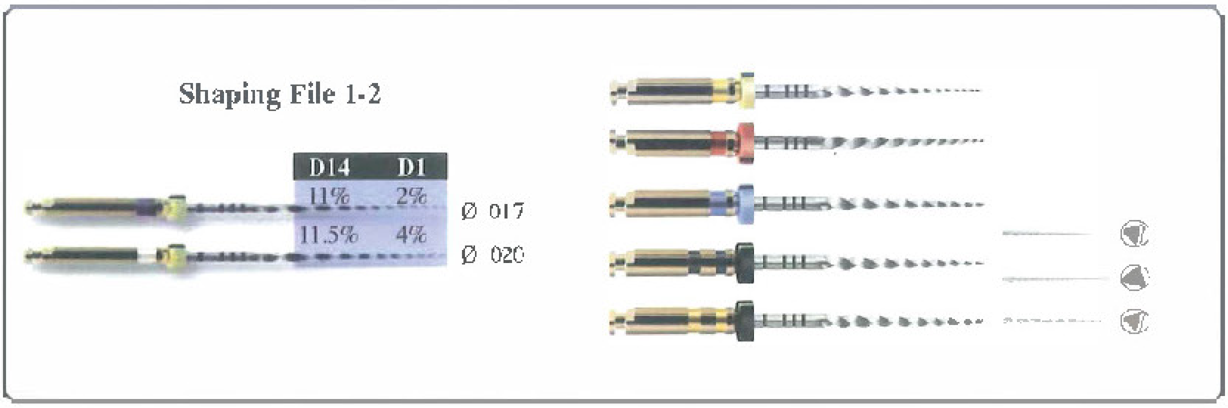


Fig. 12. Protaper system

Revo-S NiTi system

It is composed of three files (shapers and cleaners):

1- SC1:

- Which has 6% taper, 21mm length and is equivalent to size#25 ISO.
- It is intended to reverse flare the cervical and middle thirds prior to WL determination.

2- SC2 (shaper and cleaner 2):

- It has *4% taper,* 25-29 mm in length and is equivalent to size#25 ISO at D1.
- Intended to work to the full WL after WL determination either electronically or radiographically.

3- SU (shaper universal):

- With 6% taper and equivalent to size #25 ISO at D1, 25-29 length.
- Works along the full WL to finish the preparation to size #25, taper 6%.
- The unique feature in this system is that the SC1 and SU files have asymmetrical cross section. This means that the instrument is going to touch the canal walls at one point with the other two points free from the canal walls which alternate during the file rotation. So the blades touch the walls and become free alternatively during rotation leading to a snake like movement during rotation.

This contacting and freeing of the blades from the canal wall (snake-like motion) led

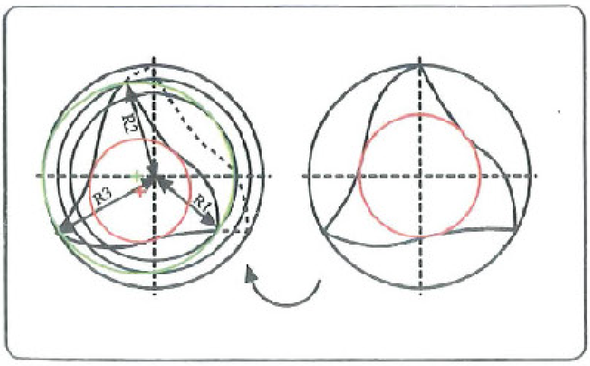


Fig. 13. Snake-like movement of the Revo-S system

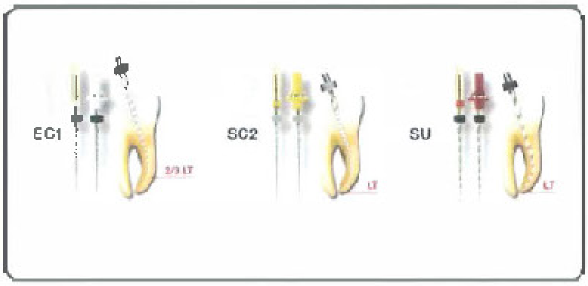


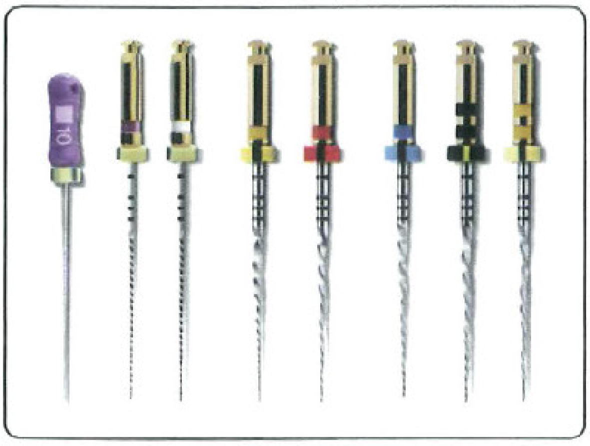
Fig. 14. Steps for using Revo-S system

to reduction of the stresses on the instrument, reduce fracture rates, better canal maneuvering and removal of the cut debris in a coronal direction.

All rotary NiTi files are designed to have non-cutting pilot tips to avoid canal ledges, perforations and apical zipping. Finally, the ideal file design is yet to develop as non of the available systems contacts the root canal walls 100% and we are still depending on root canal irrigants to clean contaminated walls, while the major role of endodontic files remains to cut and shape root canal dentin.

PROTAPER NEXT

The success achieved using asymmetric file cross-sections encouraged Maillefer Dentsply to introduce the Protaper next series which is manufactured by milling specially heat treated NiTi alloy producing the M-wire which is more flexible than regular NiTi alloys and also more resistant to torsional fatigue by about (50%). They used rectangular cross-section which only contacts the canal in two points leaving the other two points free. This has led to minimal instrument locking inside the root canal, easier canal negotiation faster preparations and less liability to instrument separation. Due to altered asymmetric cross section, the instruments are known to move in a sinusoidal movement with two blades in canal contact and two free blades (also known as snake-like motion). The system is composed of five instruments X1(017/4%), X2(025/6%), X3(030/7%), X4 (040/6%) and X5 (059/6%).



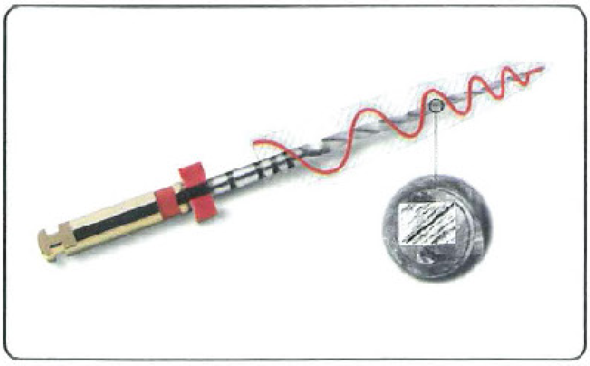


Fig. 15. Sinusoidal movement (snake-like) of the Protaper Next system

Recently special interests are being directed towards reciprocation file motion with various degrees which varies with different manufacturers, the most common systems are those produced by Maillefer Dentsply ex: Reciproc and Wave one. The interesting fact about Wave one is that its intended for single use and a single file prepares the entire canal .

The system is composed of three files; the small (021/6%) for extra small and severely curved canals, the medium (025/8%) for average sized and curves and the large (040/8%) for larger and less curved canals.

The wave one is mounted on a special reciprocating motor that rotate 150 degrees in a counter clockwise rotation and 30 degrees in a clockwise direction, ie: the major cutting is performed in a counter clockwise direction utilizing the Balanced-force concept recommended by James Rhone.

Finally the same manufacturers are producing a new NiTi alloy which is heat treated in a very special way (industrial secret) producing a golden alloy that could be memory controlled ie: has no restoring forces inside the root canal and hence more flexibility and canal curve preservation. The newly produced systems are the Protaper next Gold and the Wave-one Gold.

Never

Never exceed the recommended speed.

Never exceed the recommended torque.

Never push or force the instrument.

Never reach a locked situation.

Never increase the revolution time.

Never skip sizes.

Never work dry.

Never exceed the instrument limits.

CHAPTER REVIEW QUESTIONS

1. Discuss objectives and principles of root canal instrumentation.
2. Criticize the different methods employed to identify the end point of canal preparation .
3. Mention the different methods, materials and techniques used for root canal irrigation.
4. Discuss the historical advancements in root canal preparation techniques.
5. Mention and criticize the different automated techniques used for root canal preparation with special reference to Nickel Titanium systems.
6. Controlled memory files opened the way to new maneuvers for the clinician in both manual and rotaty fashions. Explain.

REFERENCES

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Weine FS. Endodontic Therapy 5th ed. Mosby-Year book, Inc, 1996.
- Schrader C, Ackermann M, Barbakow F. Step-by-step description of a rotary root canal preparation technique. Int Endod J. 1999 Aug; 32(4):312-20.
- Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod. 2004 Aug;30(8):559-67.
- Young GR, Parashos P, Messer HH. The principles of techniques for cleaning root canals. Aust Dent J. 2007 Mar;52(1 Suppl):S52-63.

14

Obturation of The Root Canal System

TECHNICAL & CLINICAL ENDODONTICS

Randa El Boghdad
Suzan Abdul Wanees Amin

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify the purpose of obturation and reasons why inadequate obturation may result in treatment failure.
2. Identify the technical and clinical criteria that determine when to obturate.
3. Identify the advantages and disadvantages of different obturation materials and devices.
4. Identify the steps and evaluation for fitting the master cone and the significance of depth of spreader penetration during compaction.
5. Identify the steps of cold lateral compaction of gutta percha.
6. Identify the steps of vertical compaction technique of heat softened gutta percha.
7. Identify other techniques used for obturation and their indications
8. List requirements, indications, function of sealers and available types.
9. Identify the steps of mixing and placement of sealers.
10. Describe the techniques used in removing excess sealers and obturating material from the chamber.
11. Discuss the technical and radiographic criteria for evaluating the quality of obturation.
12. Describe techniques used for removal of defective obturation.
13. List errors that might occur during obturation, their prevention, prognosis and possible treatment.

Master degree student should be able to:

1. Compare between the properties of different obturation materials and techniques.
2. Interpret the appropriate obturation techniques and materials in different clinical situations
3. Evaluate recent root canal filling materials.
4. Evaluate the clinical and radiographic criteria for quality obturation.

Ph.D student should be able to:

1. Assess the efficiency of different obturation materials and devices to achieve three dimentional obturation of various root canal systems.
2. Recommend the appropriate obturation techniques and materials in different clinical situations.
3. Evaluate recent materials and concepts of root canal obturation.

Chapter Outline

Root canal therapy may be defined as the complete removal of the irreversibly damaged dental pulp followed by thorough cleaning, shaping and filling the root canal system so that the tooth may remain as a functional unit within the dental arch.

It is essential that the root canal system, must be sealed three-dimensionally so as to prevent tissue fluids from percolating in the root canal and toxic by-products from necrotic tissue and microorganisms regressing into the periradicular tissues.

The current accepted method of obturation of prepared canals employs the use of solid or a semisolid core such as gutta-percha and a root canal sealer as a soft core.

Purpose of obturation

1. To achieve total obliteration of the root canal space so as to prevent ingress of bacteria and body fluids into root canal space as well as egress of bacteria which are left in the canal.
2. To attain fluid tight seal so as to prevent bacterial leakage.
3. To replace the empty root canal space with an inert filling material so as to prevent recurrent infection.
4. To seal the root canal space as well as to have coronal seal for long-term success of root canal therapy.

Timing of obturation

Factors influencing the appropriate time to obturate a tooth include the patient's signs and symptoms, status of the pulp and periradicular tissue, the degree of difficulty, and patient management.

Patient symptoms

- If a patient presents with sensitivity on percussion, it indicates inflammation in the periodontal ligament space that better resides first.
- With irreversible pulpitis, obturation can be completed in single visit if the main source of pain (the pulp) has been removed.

Pulp and periradicular status

- Teeth with vital pulp can be obturated in the same visit.
- Teeth with necrotic pulp may be completed in single visit if tooth is asymptomatic.
- Presence of even slight purulent exudate may indicate possibility of exacerbation.

Negative culture

The reliance on negative cultures has decreased now as false negative results can give inaccurate assessment on microbial flora and positive results do not indicate the potential pathogenicity of bacteria.

Apical extent of obturation

Obturation should be done at the level of the dentinocemental junction (DCJ) described as the minor apical diameter that ends 0.5mm short of the apical foramen in young patients and 0.7mm short in older patients Fig (1).

Thus, overextension and overfilling of the root canal system should be avoided.

Overfilling is complete obturation of the root canal system with excess material extruding beyond apical foramen. ***Overextension*** is extrusion of filling material beyond the apical foramen but the canal may not have been completely filled.

Preparation for obturation

During the cleaning and shaping process, organic pulp tissue materials and inorganic dentinal debris accumulate on the canal wall, producing a surface film of debris that is amorphous and irregular called the smear layer. The smear layer is 1 to 5 μm in thickness and can be packed into the dentinal tubules to various distances. It consists of dentin particles, remnants of vital and necrotic pulp tissue, bacterial components, and retained irrigant.

The advantages and disadvantages of the smear layer removal remain controversial; however, its removal before obturation is, usually, recommended. Keeping the smear layer predisposes to leakage through inhibiting the direct contact between the sealer and the canal walls and its further disintegration by acids and enzymes that are produced by viable bacteria. Moreover, the presence of organic debris in the smear layer might provide a reservoir of nutrients allowing bacterial growth. The presence of a smear layer may, also, decrease the effectiveness of root canal irrigants and interappointment disinfectants.

After the completion of cleaning and shaping procedures, removal of the smear layer is generally accomplished by irrigating the canal with 17% disodium ethylenediaminetetraacetic acid (EDTA) and 5.25% sodium hypochlorite (NaOCl). EDTA is the most frequently used irrigant for smear layer removal (Fig.2) because it is able to chelate and dissolve its mineralized content. Sodium hypochlorite is necessary for the removal of the remaining organic components. Irrigation with 17% EDTA for 1 min followed by a final rinse with NaOCl or saline is a recommended method. Citric acid has, also, been shown to be an effective method for removing the smear layer, as has tetracycline. An additional method for removing the smear layer involves sonic and ultrasonic instruments.

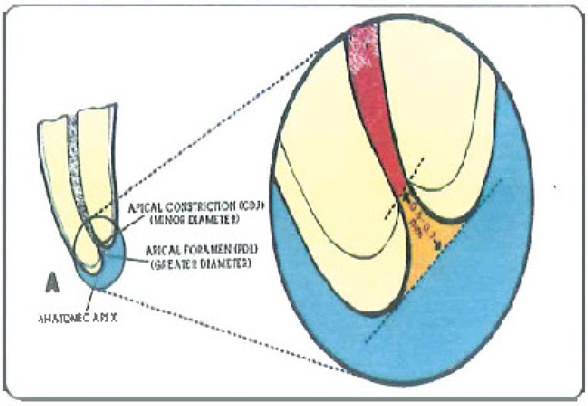


Fig. 1. Anatomy of the apex

Fig. 2. Dentine wall after smear layer removal.

Materials used for obturation

These materials may be introduced into the canals in different forms and may be manipulated by different ways. Grossman grouped acceptable filling materials into plastics, solids, cements and pastes. He also delineated ***ten requirements for an ideal root canal filling material.***

Characteristics of an ideal root canal filling material

1. Easily introduced in the canal
2. Seal canal laterally and apically
3. Dimensionally stable after being inserted
4. Impervious to moisture
5. Bacteriostatic or at least should not encourage baterial growth
6. Radiopaque
7. Non-staining to tooth structure
8. Non-irritating
9. Sterile/easily sterilized.
10. Removed easily from canal if required.

Materials used for obturation

- Plastics: Gutta-percha, resilon
- Solids or metal cores: Silver points, gold, stainless steel, titanium and irridio-platinum.
- Cements and pastes: Sealers, hydron, MTA, calcium phosphate, Gutta flow.

Gutta-percha

Gutta-percha was initially used as a restorative material and later developed into an indispensable endodontic filling material. Gutta-percha is derived from two words: GETAH, meaning gum; and PERTJA, name of the tree. Gutta-percha is a dried coagulated extract which is derived from *tropical trees*.

Chemistry

Its molecular structure is close to natural rubber, which is a *trans*-isomer of polyisoprene.

Phases of gutta-percha

Chemically, pure gutta-percha exists in two different crystalline forms, i.e. α and β which differ in molecular repeat distance and single bond form. Natural gutta-percha coming directly from the tree is in α-form while the most commercially-available products are in β-form. These phases are interconvertible.

Alpha (α) form is pliable and tacky at 56°-64°C, runny and sticky (lower viscosity), available in the form of bars or pellets and is used in many thermoplasticized obturation techniques.

Beta (β) form is rigid and solid at 42°-44°C, compactable and elongatable (higher viscosity) and is used in the manufacturing of gutta percha points and sticks.

Amorphous form exists in molten stage.

Components of commercially-available gutta-percha

Commercially-available gutta-percha, however, is composed of: 20% organic matrix (gutta-percha); 66% inorganic fillers (zinc oxide); 11% inorganic radioopacifiers (heavy metal sulphates); 3% organic plasticizers (waxes or resins). In other words, organic content including gutta percha and waxes comprises 23%, while inorganic content including filler and radioopacifiers comprises 77%.

Properties of gutta-percha

On heating, gutta-percha expands which accounts for increased volume of material which can be compacted into the root canal. Gutta-percha contracts as it returns to normal temperature. So, vertical pressure should be applied in all warm gutta-percha techniques to compensate for volume change.

Aging of gutta-percha causes brittleness because of oxidation process. Storage under artificial light also speeds up deterioration. Such brittle gutta-percha could be rejuvenated by immersing it in hot water (55°C) for 1-2 seconds and then immediately immersed in cold water for few seconds.

Gutta-percha can not be heat sterilized. For disinfection of gutta-percha points, they should be immersed in 5.25% sodium hypochlorite (NaOCl) for one minute then rinsed in hydrogen peroxide or ethyl alcohol to remove crystallized (NaOCl) that can impair obturation.

Gutta percha should always be used with sealer cement to seal root canal space as gutta-percha lacks adhering qualities.

Gutta-percha is soluble in certain solvents e.g. chloroform, eucalyptus oil, orange oil. This property can be used to plasticize gutta-percha for better filling in the canal. It has been shown, however, that gutta-percha shrinks 1-2% when it solidifies. This property could, also, be used to facilitate filling removal in case of retreatment.

Gutta-percha can also show some tissue irritation due to its high content of zinc oxide.

Advantages of gutta-percha

- Compactability: adaptation to canal walls.
- Inertness: makes it non-reactive material.
- Dimensionally stable.
- Tissue tolerance.
- Radioopacity: easily recognizable on radiographs.
- Plasticity: becomes plastic when heated.
- Dissolves in some solvents

Disadvantages of gutta-percha

- Lack of rigidity: bends when lateral pressure is applied.
- Easily displaced by pressure
- Lacks adhesive quality.

Different forms of gutta-percha

1. Gutta-percha points: standard cones of the same size and shape as that of ISO endodontic instruments.
2. Auxillary points: non-standardized cones.
3. Greater-Taper (or Increased-taper) gutta-percha points: available in 4%, 6%, 8%, 10%.
4. Gutta-percha pellets/bars: used in thermo-plasticized gutta-percha obturation techniques e.g. Obtura system.
5. Precoated core carrier gutta-percha: stainless steel, titanium or plastic carriers are precoated with alpha-phase gutta-percha e.g. Thermafil system.
6. Syringe systems: they use low viscosity gutta-percha powder e.g. Successfil and Alpha seal systems.
7. GuttaFlow: gutta-percha powder incorporated into silicone-based sealer.
8. Coated gutta-percha points: Gutta percha cones could be resin coated (e.g. EndoREZ points), glass ionomer impregnated (e.g. Activ GP), or bioceramic coated (e.g. EndoSequence BC Points).

Coated gutta-percha points

- **EndoREZ Points:** They are standard ISO-sized gutta percha points coated with a thin resin coating of polybutadiene diisocyanate–methacrylate adhesive, which bonds chemically to EndoREZ®. They are the first gutta percha points to achieve a chemical bond with EndoREZ sealer and other resin-based sealers, providing a more effective seal than traditional gutta percha.
- **Activ GP:** Activ GP (Brasseler USA) consists of gutta-percha cones impregnated on the external surface with glass ionomer (Fig. 3). Single cones are used with a glass ionomer sealer. Available in 0.04 and 0.06 taper cones, the sizes are laser verified to help ensure a more precise fit. The single cone technique is designed to provide a bond between the dentinal canal wall and the master cone.
- **EndoSequence® BC Points:** EndoSequence® BC Points™ are gutta prha cones impregnated and coated with bioceramic nanoparticles. The bioceramic particles in BC Points™ bond with the bioceramic particles found in BC Sealer™ to form a true gap-free seal.

Fig 3. Activ GP system.

Silver cones

They have been used in dentistry since 1930's but their use nowadays has declined because of their corrosion.

Silver cones contain traces of metals like copper and nickel which add up to corrosion.

The corrosion products were shown to be toxic, thus, may cause tissue injury.

Due to their stiffness, silver cones were mainly indicated in round, tapered and narrow canals. They can not conform to the canal shape as they lack plasticity; their use is, thus, not indicated in filling large, oval canals.

Silver cones do not possess adhering qualities, so a sealer is required to adequately seal the canal.

Resilon

A new material, Resilon (Epiphany) has been developed to replace gutta-percha and traditional sealers for root canal obturation.

Resilon core material is a thermoplastic synthetic polymer based (polyester) root canal filling material that contains bioactive glass and radioopaque fillers. *Resilon sealer* is a dual-cured resin based composite sealer. *Resilon primer* is a self etch primer that enables bonding of the sealer to the walls of the canal space creating a *monoblock*.

It can offer solutions to the problems associated with gutta-percha as shrinkage of gutta-percha on cooling; since it does not bind chemically to sealer, thus, results in gap formation between the sealer and gutta-percha.

Resilon only shrinks 0.5% and is chemically bonded to the sealer by polymerization; no gaps are, thus, seen due to shrinkage.

Root canal sealers

The purpose of sealing root canals is to prevent periapical exudates from diffusing into unfilled part of the canal, to avoid reentry and colonization of bacteria and to check residual bacteria from reaching the periapical tissues. Therefore, to accomplish a ***fluid tight seal***, a root canal sealer is used.

Functions of sealers

- Lubricant and aid in seating of the master cone.
- Act as a binding agent between the filling material and canal wall and between the core materials' cones if several are used.
- Fill patent accessory canals, multiple foramina, voids and irregularities.
- Antimicrobial agent.
- Have been shown to influence the outcome of root canal treatment.

Requirements of an ideal root canal sealer

Grossman listed eleven requirements of a good root canal sealer:

1. It should be tacky when mixed so as to provide good adhesion between it and the canal wall when set.
2. It should create a hermetic seal.
3. It should be radioopaque.
4. The particles of powder should be very fine so as to be easily mixed.
5. It should not shrink upon setting.
6. It should not stain tooth structure.
7. It should be bacteriostatic or at least not encourage bacterial growth.
8. It should set slowly.
9. It should be insoluble in tissue fluids.
10. It should be tolerant, non-irritating to periraduicular tissue.
11. It should be soluble in common solvents if it is to be removed.

The following were added to Grossman's 11 basic requirements:

1. It should not provoke an immune response in periradicular tissue.
2. It should neither be mutagenic nor carcinogenic.

Classification of root canal sealers (cements)

Sealers can be broadly classified according to their composition into:

1. Zinc oxide and eugenol-based.
2. Calcium hydroxide-based sealers.
3. Combination sealers.
4. Medicated sealers.
5. Silicone-based sealers.
6. Polycarboxylate-based sealers.
7. Glass ionomer-based sealers.
8. Resin-based sealers.
9. Calcium phosphate cement (e.g. Appatite root canal sealer).
10. Calcium silicate-based sealer (e.g. iRoot SP, MTA Fillapex).

1) Zinc oxide and eugenol-based sealers:

- **Rickert's formula** (or **Kerr root canal sealer**)

The original zinc oxide-eugenol sealer was developed by Rickert. It was developed as an alternative to the gutta percha-based sealers (chloropercha and eucapercha sealers) as they lack dimensional stability after setting. However, its content of silver, added for radioopacity, made the sealer extremely staining causing severe discoloration of the teeth. In 1958, Grossman recommended a non-staining formula as a substitute.

Grossman's sealer formula is as follows:

Table (1) Grossman's formula.

Powder		Liquid
Zinc oxide (reagent)	40 parts	
Staybelite resin	30 parts	
BisthmusSubcarbonate	15 parts	Eugenol
Barium Sulfate	15 parts	
Sodium Borate	1 part	

Setting time

Cement hardens approximately in 2 hours at 37°C.

Advantages

1. Extended working time but set faster in the tooth due to body temperature and humidity.
2. Plasticity.
3. Good sealing potential due to little volumetric change.

Disadvantages

Zinc eugenolate is decomposed by water through continuous loss of eugenol, which makes zinc oxide eugenol a weak unstable compound.

N.B.

To overcome the irritating quality of eugenol and the tendency of zinc eugenolate to be de composed by water, a non-eugenol sealer, **Nogenol,** was developed. The base is zinc oxide and barium sulfate as radioopacifier with other ingredients along with vegetable oil as liquid. Setting is accelerated with hydrogenated rosin, chlorothymol and salicylic acid.

2) Calcium hydroxide-based sealers:

Calcium hydroxide has been used in endodontics as an intracanal medication or as a sealer in com bination with a solid core material. Its alkalinity stimulates the formation of mineralized tissue. Calcium hydroxide-based sealers can induce mineralization, induce apical closure via cementogenesis, inhibit root resorption, inhibit osteoclast activity. They are less toxic than zinc oxide and eugenol-based sealers.

Disadvantages

Calcium hydroxide content may dissolve to release calcium hydroxide for its osteogenic effect, leaving obturation voids.

- **Sealapex**

It is a non-eugenol calcium hydroxide polymeric resin sealer delivered as two pastes in collapsible tubes. It has good therapeutic effect and is biocompatible. Extruded material resorbs in 4-5months. However, it has poor cohesive strength, and takes a long time to set (3 weeks). It absorbs water and expands on setting.

Table (2) Sealapex composition.

Base		Catalyst	
Calcium hydroxide	25%	Barium sulfate	18.6%
Zinc oxide	6.5%	Titanium oxide	5.1%
Calcium oxide		Zinc stearate	1%
Butyl benzene		Isobutyl salicylate	
Fumed silica		Disalicylate	
		Trisalicylate	
		Bisthmus oxide	

- **Apexit**

It is a calcium hydroxide based sealer available in syringes. It is biocompatible, easy to mix, radioopaque and hard setting.

3) **Combination sealers:**

- **Tubliseal**

The formula of this sealer is based on a combination of zinc oxide-eugenol and resin marketed as a two-paste system. It sets in 20 min on the glass slab and 5 min in the root canal. It is easy to mix, extremely lubricating, does not stain the tooth and expands after setting. However, it is irritant to tissues, has very low viscosity and short working time. It could be recommended when apical surgery is to be done after filling.

- **CRCS (Calcoibiotic Root Canal Sealer)**

CRCS is a zinc oxide and eugenol-eucalyptol sealer to which calcium hydroxide has been added for its osteogenic effect. It takes 3 days to fully set either in dry or humid environment. It shows very little water sorption making it quite stable. This improves sealing, but brings osteogenic effect into question.

4) **Medicated sealers:** (**N2, SPAD, Endomthasone**)

These are medicated variations of zinc oxide and eugenol-based sealers. Paraformaldehyde, and sometimes corticosteroids, was added to zinc oxide-eugenol cements. The most common denominator of these medicated sealers is formaldehyde in one form or another. These sealers constantly release formalin which causes prolonged fixation and antiseptic action. It is this dissolution that breaks the seal and leads to their destructive behavior. Since formalin is a tissue-destructive chemical, these sealers are listed as the number one irritant. The degree of irritation is severe with overfilling when N2 is forced into the maxillary sinus or mandibular canal where persistent paraesthesia is observed.

5) **Silicone-based sealers:**

- **Roeko Seal**

It shows low film thickness, good flow, biocompatibility and low solubility. Its main component is polydimethylsiloxane. Instead of showing shrinkage, it shows 0.2% expansion on setting.

- **GuttaFlow and GuttaFlow 2**

GuttaFlow and GuttaFlow2 (Coltène/Whaledent) are cold, flowable matrices that are to be triturated. They consist of gutta-percha in particulate form (less than 30 μm) added to RoekoSeal. The material is provided in capsules for Trituration (Fig. 4). The technique involves injection of the material into the canal, followed by placement of a single master cone. The material provides a working time of 15 minutes and it cures in 25 to 30 minutes. The material can fill canal irregularities with consistency and is biocompatible.

Fig. 4. GuttaFlow.

Disadvantages

The setting time is inconsistent and may be delayed by final irrigation with sodium hypochlorite.

6) Polycarboxylate-based sealers:

Polycarboxylate cement is essentially a zinc oxide and polyacrylic acid. It sets very hard, adheres well to dentin, and is insoluble in water. Unfortunately, it is viscous, sets too rapidly, and is impossible to remove; thus, has been abandoned as root canal sealer.

7) Glass ionomer-based sealers:

- **Ketac Endo**

Glass ionomer sealers have the ability to form adhesive bond with dentin. They possess good flow, low surface tension, minimum voids and good sealing ability. On the other hand, its greatest disadvantage is that it cannot be removed from the root canal in case of retreatment since there is no known solvent for glass ionomer.

- **Activ GP system sealer**

Activ GP (Brasseler USA, Savannah Georgia) consists of a glass ionomer–impregnated gutta-percha cone with a glass ionomer external coating and a glass ionomer sealer. This single-cone technique is designed to provide a bond between the dentinal canal wall and the master cone (monoblock).

8) Resin-based sealers:

Resin sealers have a long history of use, provide adhesion, and do not contain eugenol. There are two major categories: epoxy resin–based and methacrylate resin–based sealers.

A. Epoxy resin-based sealers:

- **AH-26**

AH-26 is an epoxy resin, marketed as a powder and liquid. Epoxy resin-based sealers are characterized by the reactive epoxide ring and are polymerized by the breaking of this ring. The original formulation has been altered with the removal of silver as one of the constituents to prevent tooth discoloration. It sets slowly in 24 to 36 hours at body temperature. It is not sensitive to moisture and sets even under water but will not set in the presence of hydrogen peroxide.

Advantages

1. Good adhesive property to dentin especially with the removal of the smear layer.
2. Good flow.
3. Antibacterial.
4. Contracts slightly on hardening.
5. Low toxicity and well tolerated by periapical tissues.

Disadvantages

As it sets, AH-26 releases traces of formaldehyde temporarily.

- **Thermaseal**

A formulation that is very similar to AH-26 and highly rated for sealing ability and tissue tolerance. It can be used with warm condensation obturation techniques.

- **AH Plus (also Topseal)**

It is an epoxide-amine resin sealer developed from its predecessor AH-26 because of color and shade stability; the material of choice for aesthetic demands. It is a two-paste system that closely adapts to dentin walls with minimal shrinkage upon setting as well as outstanding dimensional stability and sealing properties. Its working time is 4 hours and its setting time is 8 hours. Its composition is as follows:

Table (3) AH Plus composition.

Epoxide Paste	Amine Paste
Diepoxide	1-adamantane amine
Calcium tungstate	N,N'-dibenzyl-5-oxa-nonandiamine-1,9
Zirconium oxide	TCD-Diamine
Aerosil	Calcium tungstate
Pigment	Zirconium oxide
	Aerosil
	Silicone oil

In addition to the tubes' delivery, the proven and unchanged AH Plus sealer chemistry is now available as **AH Plus Jet™ Mixing Syringe (Fig.5)**. The new double-barrel syringe significantly improves working ergonomics. AH Plus Jet comes with a mixing tip, which automatically mixes the sealer components in ideal ratio. It is equipped with an intra oral tip adjustable to individual anatomic conditions through rotation and angulation. Thus, AH Plus Jet allows direct application of the sealer into the root canal orifices. The sealer can be clinically applied with a single hand.

Fig. 5. AH Plus Jet.

B. Methacrylate resin-based sealers:

Four generations of methacrylate resin-based sealers (MRBS) have been marketed for commercial use.

- **First-generation methacrylate resin-based sealers**

Hydron (Hydron technologies, Inc. Pompano Beach, FL, USA) is a rapid setting, hydrophilic plastic injectable material to be used without a core and was extensively used to fill the root canals in the late 1970s. It consists of 2-hydroxy ethyl methacrylate (HEMA). It is a biocompatible material. However, it has a short working time and very low radioopacity. It is irritant to the periapical tissues and difficult to remove. Hydron is an example of a primary monoblock

- **Second-generation methacrylate resin-based sealers**

Second-generation MRBS materials do not depend on separate dentin conditioning. This generation is dependent on the penetration of the hydrophilic sealer into the dentinal tubules and lateral canals following removal of the smear layer. This forms a hybrid layer by creating resin tags with the collagen network. An example of this generation is **EndoREZ Sealer** (Ultradent Products, South Jordan UT). EndoREZ was introduced by coating gutta-percha; cones with a polybutadiene diisocyanate–methacrylate adhesive. The sealer can be used with gutta-percha or with resin coated gutta-percha; the latter with the objective of forming a monoblock. It is a two component system in a double-barrel autotomix syringe. The sealer has hydrophilic qualities and, hence, can be used in root canals that pose a challenge of moist environment. In this system, no dentin adhesive is employed. Bonding between the gutta percha cone and the sealer, which in turn can bond well to the canal wall, could establish a complete monoblock seal.

- **Third-generation methacrylate resin–based sealers**

As the resin era improved, a third generation of self-etching sealers was introduced, which contained self-etching primer along with dual-cured resin sealer for root canal obturation procedures. This introduces the concept of incorporating the smear layer in the sealer–dentin interface. Examples of this generation are **Epiphany** (Pentron Clinical Technologies) and **RealSeal** (SybronEndo, Orange, CA, USA).

Epiphany is a third generation dual-cure resin-based sealer. This system uses a self-etching primer and comprises a Resilon cone (Fig. 6). The Epiphany sealer, being dual cure, takes about 45 minutes to completely self-cure in the canal, and hence presents ease of handling. It can be light cured to achieve a hard coronal seal immediately to prevent any contamination issues. The premise behind the material is the formation of a monoblock, that is, the primer forms a hybrid layer with dentin,which bonds to sealer and then bonds to the Resilon core. Resilon/Epiphany sealer was then introduced again as **RealSeal** by adding a thinning solvent ethoxylated bisphenol-A-dimethacrylate to adjust the viscosity but did not include photoactivation.

Fig. 6. The Epiphany system.

Fourth-generation methacrylate resin–based sealers

Fourth-generation MRBSs are functionally similar and comparable to self-adhesive resin luting composites in that they have further eliminated the separate etching/bonding step. Dentin-adhesive primers are now incorporated into the resin-based sealer/composite to render them self adhesive to dentin substrates. The combination of an etchant, a primer, and a sealer into an all-in-one self-etching, self-adhesive sealer is advantageous in that it reduces the application time as well as errors that might occur during each bonding step. Therefore, in theory, the bonding mechanism of self adhesive sealers is similar to self-adhesive resin materials. These materials are relatively new, and detailed information and research is limited. Examples of this generation are **MetaSEAL** (Parkell) and **RealSeal SE and RealSeal 1** (SybronEndo).

MetaSEAL is the first commercially available,

fourth-generation, self-adhesive, dual-cured sealer. It is recommended for use exclusively with cold compaction or single cone techniques. The sealer purportedly bonds to thermoplastic root-filling materials as well as radicular dentin via the creation of hybrid layers in both substrates.

RealSeal SE is the simplified, dual-cured version of RealSeal The acidic resin monomers in the self etching primer are incorporated in the RealSeal SE sealer, thus making the technique an all-in-one step. The sealer is claimed to bond to both the Resilon core and radicular dentin via hybrid layers in both substrates, leading to a monoblock unit.

9) Calcium Phosphate Cement:

- ***Appetite Root canal Sealer***

Several root canal sealers composed of hydroxyapatite and tricalcium phosphate have been promoted. They are in a powder and liquid form where the liquid is polyacrylic acid and water.

10) Calcium silicate-based sealers:

They are sealers that have calcium silicate as their main component, set hard and are stable in constantly wet environment. They have good sealing ability and biocompatibility and stimulate periodontal regeneration. They can be either mineral trioxide aggregate (MTA)-based sealers or bioceramic based sealers.

A. MTA-based sealers

MTA is composed principally of Portland cement with the addition of bismuth trioxide to render it radiopaque. Hydration of MTA forms calcium silicate hydrate (CSH) gel that adheres to the gutta-percha cone. As a sealer, it adheres well to dentin and core obturating material, has cohesive strength and wetting properties, and has low viscosity and low cytotoxicity. The novel sealer based on MTA has efficacious sealing ability. When in contact with simulated body fluid, it releases calcium ions in solution and encourages the deposition of calcium phosphate crystals. However, MTA-based root canal sealers still do not fulfill all the criteria described by Grossman. Currently, Examples of MTA sealer formulations are **MTA Fillapex** (Angelus Odonto) and **ProRoot Endo Sealer** (Dentsply Maillefer, Ballaigues, Switzerland).

MTA Fillapex is made of two pastes. The first paste contains MTA-based salicylate resin, bismuth trioxide, and fumed silica. The other MTA-Fillapex paste contains fumed silica, titanium dioxide, MTA (40%), and base resin. Salicylate resin is tissue friendly. MTA within the mixture reacts with water from the dentinal fluid. It exhibits an alkaline pH, has a good flow rate, has a working time of 35 minutes, is antimicrobial, and has a low film thickness to easily penetrate into the accessory canals. However, it can be very soluble.

Pro-Root Endo Sealer is another calcium silicate–based endodontic sealer. The major components are tricalcium silicate and dicalcium silicate, with inclusion of calcium sulfate as setting retardant, bismuth oxide as a radiopacifier, and a small amount of tricalcium aluminate necessary for the initial hydration reaction of the cement. The liquid part consists of viscous aqueous solution of a water soluble polymer to improve the workability and flow without affecting its biocompatibility of the material.

B. Bioceramic-based sealers

The properties associated with bioceramics, such as being nontoxic, are very advantageous to dentistry. They can be classified as bioinert, bioactive, or biodegradable. Bioinert materials do not interact with biological systems. Bioactive materials are durable tissues that can undergo interfacial interactions with surrounding tissue. Biodegradable materials are eventually replaced or are incorporated into tissue. Numerous bioceramics are currently in use in dentistry. Calcium silicates such as MTA and BioAggregate (DiaDent, Burnaby, BC, Canada) are examples of bioactive bioceramics. They are nontoxic, biocompatible, do not shrink, and are chemically stable within the biological environment. They do not result in an inflammatory response if an overfill occurs during the obturation process and have the ability to form hydroxyapatite and to create a bond between dentin and the appropriate filling materials. A bioceramic based sealer, however, is a term usually used with sealers that are bioaggregate-based sealers. Examples of bioceramic-based sealers are iRoot SP (injectable root canal sealer) (InnovativeBioCeramix, Vancouver, BC, Canada) that is also known as EndoSequence BC Sealer (Brasseler) (Fig. 7). The major inorganic constituents include tricalcium silicate, dicalcium silicate, calcium phosphates, colloidal silica, and calcium hydroxide. It, also, contains zirconium oxide as a radiopacifier and a water free-vehicle that thickens the paste system. It is available as a premixed paste in a syringe with intraoral tips to deliver the paste inside the root canals.

Fig. 7 EndoSequence BC sealer.

Monoblock concept

The term monoblock, meaning a single unit, has been employed in dentistry since the turn of the century. A monoblock obturation system is the unit in which the core material, sealing agent, and the root canal dentin form a single cohesive unit. There are two prerequisites for the monoblock to function as a mechanically-homogeneous unit. First, the materials that constitute the monoblock should have the ability to bond strongly and mutually to each other, as well as to the substrate that the monoblock is intended to reinforce. Second, these materials should have a modulus of elasticity that is similar to that of the substrate. Monoblocks in the root canal spaces may be classified as primary, secondary, or tertiary depending on the number of interfaces present between the bonding substrate and the bulk material core (Fig. 8).

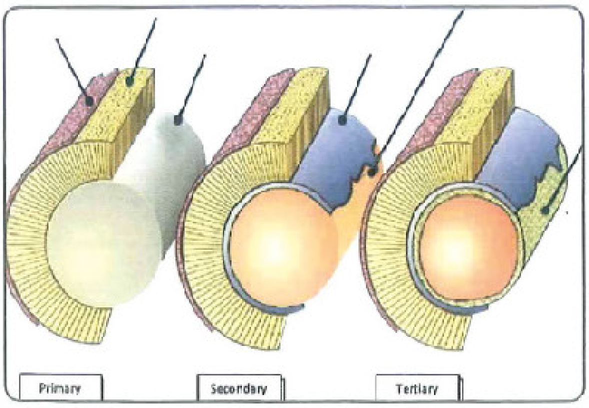


Fig. 8. The monoblock concept.

Primary monoblock

Primary monoblock has a single interface that extends circumferentially between the material and the root canal wall. Hydron and MTAare examples. Orthograde obturation with MTA (ProRoot MTA, Dentsply Tulsa) as an apexification material represents a contemporary version of the primary monoblock in attempts to strengthen immature tooth roots. The lack of sufficient strength and stiffness is the major drawback, and this led to the development of secondary monoblocks.

Secondary monoblock

Conventional sealers do not bond strongly to dentin and gutta-percha; therefore, gutta-percha does not form a monoblock, even with the use of a resin-based sealer. Although glass ionomer cements and resin-modified glass ionomer cements bond to root dentin and have been marketed as root canal sealers, they do not bond to gutta-percha. The combined use of a sealer and a core material introduces additional interfaces into a monoblock during obturations. Secondary monoblocks have two circumferential interfaces, one between the cement and dentin and another between cement and the core material. This is of great importance in restorative and endodontic practice. A classic example is the use of sealer for obturation, wherein one interface is between the gutta-percha point and sealer and the second one is between the sealer and the root canal wall. Examples are Resilon and iRoot SP. The concept was to create a root canal monoblock to achieve a total bond and a total seal of the root canal space.

Tertiary monoblock

A third circumferential interface is introduced between the bonding substrate and the abutment material by coating the non-bondable gutta-percha with materials that make them bondable to the sealers, thus, creating tertiary monoblocks. Because the tertiary interface exists as an external coating on the surface of the gutta percha,

such systems are designed to be used with either a single-cone technique or placement of accessory cones without lateral compaction, to avoid disrupting the external coatings. Examples of tertiary monoblock are ActiveGP and EndoREZ (Ultradent, South Jordan, UT).

Testing the proper consistency of sealers

The root canal cement should be mixed to a thick creamy consistency. It should not be mixed too thin, but also not so viscous that it will not flow between gutta-percha points or penetrate surface irregularities, accessory and lateral canals. The ideal consistency permits ample clinical working time and minimal dimensional change. The following methods are used to determine the ideal consistency of the cement mix (Fig. 9):

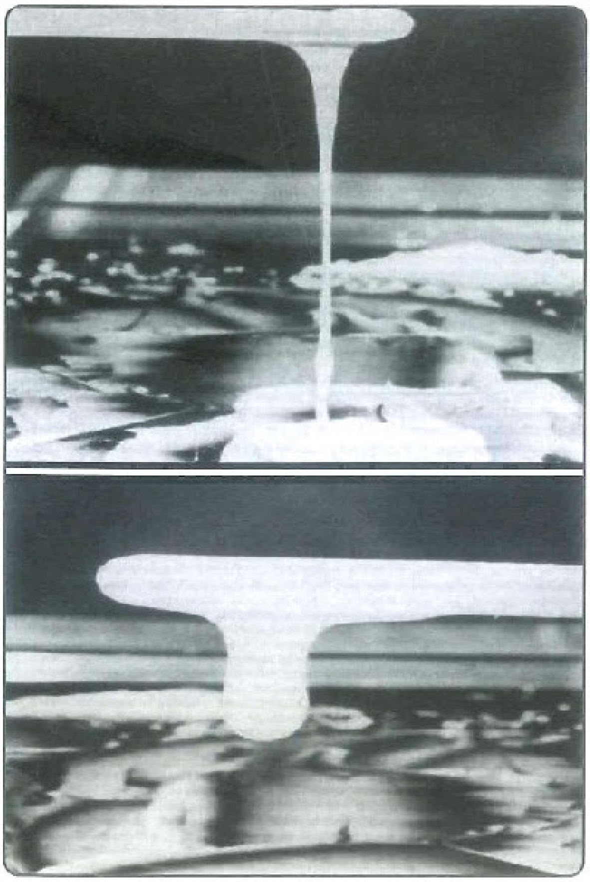


Fig. 9. Testing sealer consistency.

- ***Drop Test:***

The soft cement mix is gathered onto the spatula which is then held *edgewise*. The cement mass should not drop off the spatula's edge in less than 10 to 12 seconds.

- ***String-out Test:***

The flat surface of the spatula is placed on the top of the cement mix and then lifted up slowly. The cement should string out at least an inch without breaking.

Methods of sealer placement

Various methods are employed. The common of which are:

1. Coating the master cone and placing the sealer in the canal with a pumping action.
2. Using a Lentulo spiral.
3. Placing the sealer on the final file used at the working length and turning the file counterclockwise.
4. Injecting the sealer with special syringes.

Radiographic evaluation of the quality of filling

The radiographic criteria for evaluating obturation include the following categories: length, taper, density, gutta-percha and sealer removal to the facial cemento-enamel junction in anterior teeth and to the canal orifice in posterior teeth, and an adequate provisional or definitive restoration.

Obtaining the Master Point (Initial point, Primary point)

When the canal is ready for filling, the fit of the master point is the most important. Gutta-percha has been standardized in size and shape to match the standardized instrument. Presumably, a master point the same size of the instrument that prepared the apical third of the canal will fit exactly. However, the point must be tested in place; which is known as the 'trial point measurement'.

Before insertion, the master point should be sterilized. Gutta-percha points may be sterilized with a germicide for 5 min in sodium hypochlorite (5.25%) or hydrogen peroxide (3%) or chlorhexidine (2%). Silver point is held in a plier and heated over a low flame for a few seconds. The silver point should then be immersed in a germicide; which cools the point and also anneals it making it more flexible.

The master point should fulfill the following criteria:

1. Its adjusted length is sufficient to reach the apical end of the canal.
2. The diameter of its apical end fits the diameter of the apical terminus.
3. Its apical third completely fills the apical third of the canal.

The three methods used to determine the proper fit of the master cone are:

1. **Visual test:**

The master point is measured and grasped with the cotton pliers at a position equal to the prepared length of the canal. The point is then carried into the canal until the pliers touch the external reference point of the tooth. If the working length of the tooth is correct and the point goes completely to position, the visual test has been passed.

If the point extended beyond the apex, it means that the apical foramen was originally large or has been perforated. The next larger size point should be tried. If the larger point does not go into place, the original point may be used by cutting 1 or 2 mm off the tip. Each time the tip is cut back, the diameter becomes larger. The point is retried in the canal until it goes into the correct position.

2. **Tactile test:**

In this method, the practitioner depends on the tactile sensation to determine whether the point tightly fits the canal as determined by the apical 3 or 4 mm of the canal, being prepared with somewhat parallel walls. In such case, some force should be required to seat the point and, once in position, a pulling force should be required to dislodge it. This is known as "tugback".

If the point is loose in the canal, the next larger point is tried, or the method of cutting segments from the tip of the master point, followed by trial and error positioning should be used.

3. **Radiographic test:**

After the visual and tactile tests, the point position must be checked radiographically to show that the point is extending to within 1 mm from the radiographic apex.

If the radiograph shows the point forced well beyond the apex, the over-extended point should be shortened from the fine end and then retried. In any case, it should never be pulled back to the proper working length; otherwise, it would be loose in the canal (Fig. 10).

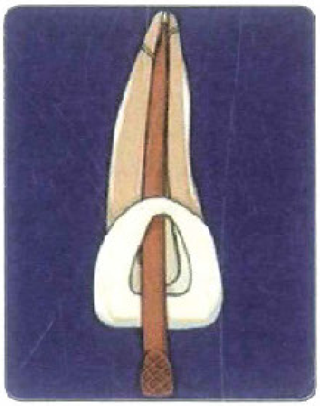


Fig. 10. Master cone fitting

Methods of obturation

The main objective of obturation is the three-dimensional sealing of the root canal system. Gutta-percha is still the most common material used for root canal obturation, however, a sealer is always required to lute the material to the root canal wall and fill canal wall irregularities.

I. *Cold gutta-percha technique:*

- Lateral compaction technique.
- Variations of lateral compaction technique.

II. *Chemically-softened cold gutta-percha:*

- Callahon-Johnston technique.

- Chloroform dip technique

III. *Warmed gutta-percha technique:*

- Vertical compaction technique.
- System B continuous wave condensation technique.
- Sectional compaction technique.
- Warm lateral compaction technique.

IV. *Thermomechanical compaction:*

- McSpadden technique.
- Ultrasonic plasticizing.

V. *Thermoplasticized injectable gutta-percha:*

- Obtura III
- Ultrafil 3D

VI. *Solid-core carrier insertion:*

- - Thermafil
- - SuccessFil
- - SimpliFill

I. *Cold gutta-percha techniques:*

• *Lateral compaction technique:*

This technique has long been the standard against which other techniques of obturation have been judged. It involves the placement of tapered gutta-percha cones in the canal and then compacting them under pressure against the canal wall using a spreader. The canal needs to be continuously tapered with a definite apical stop.

Technique:

- After canal preparation, select a master cone based on the diameter of the largest file used in the canal up to the working length. Master point is notched at the working distance analogous to the level of incisal or occlusal reference point. The master point should be checked visually, radiographically and by tactile sensation.
- Select the size of the spreader to be used that should fit within 1-2 mm of the true working length and, when introduced into the canal with the master cone in place, it should be within 2 mm of the working length. A silicone stop should be placed on the shaft of the spreader to mark the working length (minus 1-2mm). There seems to be a correlation between establishing a seal and the depth of spreader penetration.
- The canal should be dried by absorbent paper points before obturation. More than one point might be needed.
- Apply the sealer into the prepared canal (as previously discussed).
- The premeasured master point is coated with sealer and placed into the canal. The preselected spreader is then introduced alongside the master point. With a rotary vertical motion, the spreader is slowly moved apically to full penetration marked on the shaft with the silicone stop. Spreader helps in gutta-percha compaction. It acts as a wedge to squeeze the gutta-percha laterally under vertical pressure not by pushing it sideways.
- The spreader is then removed from the canal by rotating it back and forth. This compacts gutta-percha and a space gets created lateral to the master point.
- An accessory (auxiliary) point is placed in the space left by the spreader and the above procedure is repeated until the spreader can no longer penetrate beyond the cervical line. Some practitioners prefer to coat each point with additional sealer but this is not necessary.
- The protruding points are then severed at the orifice of the canal with a very hot instrument. All the sealer and gutta-percha should be removed from the pulp chamber and a final radiographis takentaken (Fig. 11).

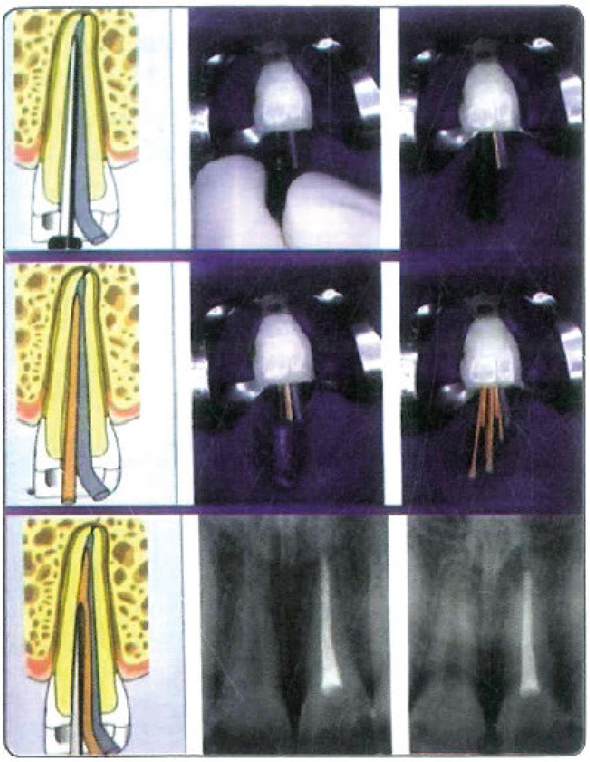


Fig. 11. Lateral compaction technique

• *Variations of lateral compaction technique*

Sometimes the wide variations in the root canal shape require variations in the master point technique.

1. ***Inverted point technique:***

This technique is applicable in the tubular canals in teeth suffering early death of the pulp. Tubular canals are generally large canals with parallel walls. Since these canals do not have an apical constriction, the main criterion is to seal the apical foramen in order to permit the compaction of obturating material.

A "coarse" gutta-percha cone is selected and the "*butt*" end of the point is carefully removed with a scalpel. The point is inverted and tried in the canal. It should visibly go to the full length and exhibit "tugback" when an attempt is made to remove it. Radiographically, it should be at optimum position.

The inverted point may act as a plunger during insertion after the walls of the canal have been coated with cement. This is due to the shape of the canal and the tight fit of the point. The patient may complain of discomfort due to air evacuation; however, if the point is slowly placed, relatively little cement will be forced periapically.

2. ***Tailor-made gutta-percha technique:***

If the tubular canal is so large (e.g. blunderbuss canal) so that the largest inverted point is still loose in the canal, a tailor-made point must be used as a master point.

Tailor-made gutta-percha point may be made by heating a number of gutta-percha points and combining them "*butt-to-tip*", until a roll has been developed much the size and shape of the canal (Fig. 12). The roll must be chilled with a spray of ethyl chloride or ice water to stiffen the gutta-percha before its fitting in the canal. If still loose, more gutta-percha points must be added. If it is only slightly too large, the outside of the roll can be flash-heated over the flame and the roll forced to proper position in the canal. By this method, an impression of the canal is actually secured.

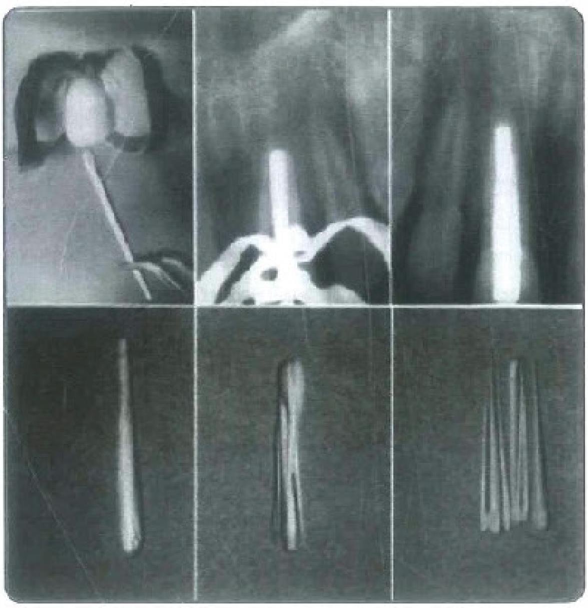


Fig. 12 Variations of lateral compaction technique.

The rolled gutta-percha should be tested for "tugback" as well as radiographically. It should then be cemented in place. The filling of the canal should then proceed following the steps of the lateral compaction technique (as previously discussed).

The outer surface of the gutta-percha roll may also be softened by dipping in chloroform, eucalyptol or halothane and inserted into the canal. By repeating this exercise, an internal impression of the canal is taken. A mark is made on the buccal side of the roll and is dipped in alcohol to stop the action of the solvent.

3. ***Ultrasonics for obturation:***

An alternative to lateral compaction with finger spreaders is ultrasonics.

II. *Chemically-softened cold gutta-percha techniques:*

This technique is a modification of the lateral compaction technique involving a solvent to soften the master point in an effort that it better conforms to the aberrations in the apical canal anatomy.

- ***Callahan-Johnston technique:***

This is an old obturation technique in which too much of the solvent, chloroform, was used to dissolve small pieces of gutta-percha to form a thick creamy mix ready for immediate filling of the root canal. However, it was found that as the chloroform evaporates in the canal, it produces a 24% decrease in volume of the filling material leading to serious leakage. Not only does the gutta-percha shrink as the solvent evaporates, but the sealer leaks as well, probably due to solvent dissolution. Spreading of chloroform through the periapical tissue might be a source of irritation.

- ***Chloroform Dip technique:***

Today's use of solvents is quite modest in comparison to the old method. In this technique,

- The master point is blunted and fitted 2 mm short of the working length. The apical 2-3mm is the dipped in the solvent for 3-5 seconds then the softened cone is inserted into the canal with slight apical pressure till the working length is reached.
- Care should be taken to moisten the canal with irrigation to avoid the sticking of soft gutta-percha to the canal walls.
- A radiograph is taken to verify the fit and correct working length of the cone.
- The cone is then removed, the canal coated with sealer and the cone is cemented in the canal.
- A finger spreader is then placed to create a space alongside the master point, then accessory points are placed until the canal is filled and the protruding canal gutta percha points are cut using a hot instrument.

The principal solvent used in the technique is chloroform which was claimed to be carcinogenic. Other solvents, such as eucalyptol and halothane, became as substitutes for chloroform.

III. *Warmed gutta-percha technique:*

• *Vertical compaction technique:*

Schilder introduced a concept of cleaning and shaping root canals in a conical shape, and then obturating the space, three dimensionally filling all the portals of exit with the maximum amount of gutta-percha and the minimum amount of sealer, with gutta-percha warmed in the canal and compacted vertically with pluggers.

Basic requirements of a prepared canal to be filled by this technique are:

I. Continuous tapering funnel-shaped from orifice to apex.

II. Apical opening kept as small as possible.

The critical step of fitting the master cone is the key to success in this technique. A suitable gutta-percha cone is chosen and placed in the canal to reach the apical terminus of the canal. The cone is removed and slightly cut back short

(1-2 mm) of this length. This allows heat molding of the round cone into the apical constriction and minimizes sealer tissue contact. When the gutta percha cone is warmed and compacted, it fills the critical parts of the canal including the shaped and cleaned apical constriction. The cone must fit tightly in the apical third, i.e. have "tugback", and have diminished taper toward the middle and coronal thirds as well.

A set of pluggers should be used for vertical compaction of the warm gutta-percha. A wider plugger is chosen for the coronal third of the canal, a narrower plugger for the middle third, and the narrowest plugger for the apical third.

A heat carrier, an instrument designed much like a spreader, is used to transfer heat from a heat source, e.g. flame, to the gutta-percha. It is heated "cherry-red", immediately carried into the canal, penetrated into the gutta-percha and left there for 2-3 seconds to allow heat transfer. It is then withdrawn in a slightly circular wiping motion. Some of the gutta-percha will be attached with the heat carrier. Vertical compaction immediately follows.

The 'Touch 'n Heat', 'DownPak' and 'System B' are electronic devices alternative to applying heat with a flame-heated instrument.

Step-by step technique

- Dry the root canal with paper points.
- Fit the appropriate gutta-percha cone to the radiographic terminus. It should visually go to full working length and exhibit "tugback". Confirm the position radiographically. Cut off the butt end at the reference point.
- Remove the cone and cut back about 1 mm of the tip, reinsert and check the length and "tugback". The cone's apical diameter should fit in 1-2 mm of the apical stop because when softened material moves apically into prepared canal, it adapts more intimately to the canal walls.
- Select the heat transferring material and pre-fit the three pluggers to the prepared canal at 5 mm intervals, i.e. the widest (coronal), the middle, and the narrowest (to within 3-4 mm of the apical constriction).
- Lightly coat the walls of the canal with sealer using a handy Lentulo spiral.
- Coat the apical third of the gutta-percha cone with a thin layer of sealer and insert it fully into place.
- Using the heat transfer instrument, trim off the surplus of the cone in the pulp chamber down the cervical third of the canal transferring heat to the coronal third of the gutta-percha cone.
- Using the widest plugger, coated with cement powder, as separating medium, the gutta-percha is compacted in an apical direction with sustained pressure. This is the *first heat wave* in which the gutta-percha temperature has been raised 5 to 8 degrees above body temperature. At this temperature (42°C to 45°C), the gutta-percha retains its crystalline "beta" form with minimal shrinkage as it cools back to body temperature.
- The *second heat wave* begins by introducing the heat carrier back into the gutta-percha, where it remains for 2-3 seconds, and when retrieved carries with it a small piece of softened gutta-percha (selective gutta-percha removal). Immediately, the mid-sized plugger is submerged into the warm gutta-percha which is compacted apically. The vertical pressure also exerts lateral pressure.
- In the *third heat wave*, heating with the heat carrier warms the next 3-4 mm of gutta-percha and again a small amount is removed. The narrowest plugger is immediately inserted in the canal and the surplus material along the walls is folded centrally into the apical mass. The warmed gutta-percha is then vertically compacted and the material flows into and seals the apical foramen.
- The apical "down-pack" is now completed and, if a post is to be placed at this depth, no more gutta percha need to be used.

- The rest of the canal may be filled by "backpacking". This method consists of placing 3 mm segments of gutta-percha in the canal, cold welding them with the heat-carrier, and then compacting. This sectional procedure is continued with heat and the next wider plugger until the entire canal is obturated.
- An alternative method of "backpacking" may be done by injecting plasticized gutta-percha from one of the syringes, such as Obtura II. The plasticized gutta-percha must be compacted with vertical pluggers to ensure its flow into portals of exit (accessory canals), to weld it to apical mass, and to minimize shrinkage.
- Finally, thorough cleansing of the pulp chamber is done, and a permanent restoration is coronally placed (Fig. 13).

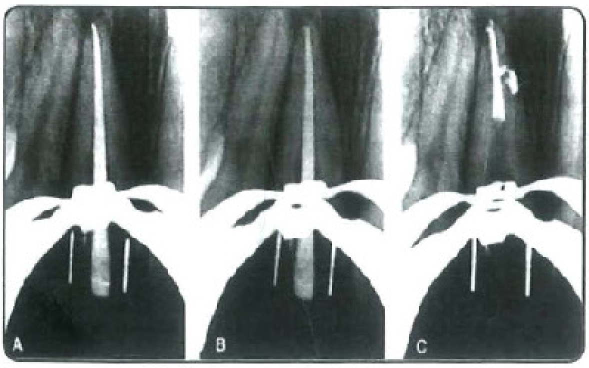


Fig. 13. Vertical compaction technique.

Advantages of vertical compaction techniques

- Excellent sealing of canal apically, laterally, and obturation of lateral as well as accessory canals.

Disadvantages of vertical compaction techniques

- Increased risk of vertical root fracture.
- Overfilling of canals with gutta-percha or sealer from apex.
- Time-consuming.

• *Continuous wave of condensation technique (System B):*

System B is a newly-developed device by ***Buchanan*** for warming gutta-percha in the canal. It monitors temperature at the tip of heat carrier pluggers, thereby delivering a précised amount of heat.

Advantages of system B

- It creates single wave of heating and compacting, thereby compaction of filling material can be done at the same time when it has been heat softened.
- Excellent apical control.
- Less technique sensitive.
- Fast, easy and predictable.
- Thorough condensation of the main canal and lateral canals.
- Compaction of obturating materials occurs at the levels simultaneously throughout the momentum of heating and compacting instrument apically.

• *Sectional compaction technique (Chicago technique):*

In this technique, small pieces of gutta-percha cones are used to fill the sections of the canal.

Technique

- A gutta-percha cone of the same size of the prepared canal is selected then blunted at the tip to fit 1mm short of the working length and cut into sections 3-4 mm long.
- A plugger is selected which loosely fits within 3 mm of the working length.
- Sealer is placed into the canal.
- The coronal end of gutta-percha is mounted to heated plugger, and the gutta-percha tip is warmed by passing it through a flame, quickly coated with sealer then carried into the canal and apical pressure is given. After this, disengage the plugger from gutta-percha by rotating it.
- Radiograph is taken to confirm its fit. If satisfactory, fill the remainder of the canal in the same manner or backfilling may also be done with one of the thermoplasticized

gutta-percha techniques.

Advantages of sectional compaction techniques

- Sealing of canal apically and laterally.
- In case of post construction only the apical part is filled.

Disadvantages of sectional compaction techniques

- Time consuming.
- Overfilling of canals with gutta-percha makes it difficult to remove.

• Warm Lateral compaction technique :

Vertical compaction causes dense obturation of the root canal, while lateral compaction provides length control and satisfactory ease and speed. Advantages of both techniques are provided by ***Endotec II*** device which helps the clinician to employ length control with warm gutta-percha technique. It comes with a battery which provides energy to heat the attached plugger and spreader. EndoTwinn is another instrument also used for warm lateral compaction with the ability to vibrate the electronically-heated tip.

Technique

- Adapt master cone gutta-percha in the canal with a sealer.
- Select Endotec plugger and activate the device.
- Insert the heated plugger in canal beside the master cone to within 3-4 mm of the apex using light apical pressure.
- Afterwards, unheated spreader can be placed in the canal to create more space for accessory cones. This process is continued until the canal is filled.

Advantages of lateral/vertical compaction technique

- Three-dimensional obturation.
- Better sealing of accessory and lateral canals.
- Endotec can be used to soften and remove gutta-percha.

IV. *Thermo-mechanical compaction techniques:*

• McSpadden compaction technique :

McSpadden introduced a technique in which heat was used to lower the viscosity of gutta-percha and thereby increase plasticity. This technique involves the use of a compacting instrument (*McSpadden compactor*) which resembles reverse Hedström file. This is fitted into latch type handpiece and rotated at 8000-15000 rpm alongside gutta-percha cones inside the canal walls. At this speed, heat produced by friction softens the gutta-percha and designs of blade forces the material apically.

Because of its design, the blades of the compactor break easily if it binds, so should be used in straight canals only. In Europe, Maillefer introduced a new condenser and Zipperer modified the reverse screw design (reverse Hedström) to an instrument more closely resembling an inverted K-file. Nowadays, McSpadden's newer modification is in form of *Microseal system* which has a *NiTi condenser*, made of nickel titanium. The new condenser is gentler and slower-speed model used in an electrically-driven NT-Matic handpiece. Because of the condeser's flexibility, it can be used in slightly curved canals. Heat-softened, alpha-phase gutta-percha as well as regular gutta-percha points are used in conjuction.

Technique

- The master cone is selected.
- Sealer is placed in the canal.
- The master cone is placed in the canal followed by the appropriate-size condenser (one that will reach near the working length).
- To form a firm mass, the condenser is spun in the canal at 1000-4000 rpm which flings the gutta-percha laterally and vertically.

Advantages

- Requires less chair time.
- Ease of selection and insertion of gutta-percha.
- Dense, three-dimensional obturation.

Disadvantages

- Liability to use in narrow and curved canals.
- Frequent breakage of compactor blades.
- Overfilling.
- Shrinkage of gutta-percha on cooling.

• *Ultrasonic plasticizing:*

This technique depends on plasticizing gutta-percha in the canal with an ultrasonic instrument. A special insert (PR 30) is used in a Cavitron Ultrasonic Scaler. The sealer and gutta-percha points are placed to virtually fill the canal. The endodontic instrument attached to the Cavitron is then inserted into the mass and activated without the coolant to plasticize gutta-percha by friction. Final vertical compaction could be done with hand and finger pluggers.

V. *Thermo-plasticized injectable gutta-percha obturation:*

• *Obtura III Heated Gutta-Percha System (Fig. 14):*

This technique was introduced in 1977 at Harvard institute. It consists of an electric control unit with pistol grip syringe and specially-designed gutta-percha pellets which are heated to approximately 185-200°C for obturation. In this, regular beta-phase gutta-percha is used. At this temperature, the gutta-percha would flow through either a 20-gauge needle (equal to size 60 file) or 23-gauge needle (equal to size 40 file). These needles are fitted to a "gutta-percha gun". The injection needle and pluggers must be initially tried for size in the canal. They must both reach 3-5 mm from the apical terminus and fit loosely at this point. Silicone stops are placed on pluggers of adequate diameter to ensure they will move the softened material and not just "punch" through it.

For canals to be filled with Obtura III, they need to have:

- Continuous tapering funnel shape for unrestricted flow of softened gutta-percha.
- A definite apical stop to prevent overfilling.

Technique

- The root canal should be thoroughly dried and a thin layer of sealer placed at the pre-chosen depth short of the apex. Excessive sealer should be avoided as it causes pooling.
- The Obtura III needle is introduced in the canal and a deposit of gutta-percha is made. The canal may be totally filled as the needle is withdrawn or a small deposit may be made and compacted with the intention of filling the canal segmentally.
- Once the deposit is placed, the pre-measured plugger is rapidly used to move gutta-percha apically. A drop of sealer on the tip of the plugger will prevent adhering of the gutta-percha.
- When the apical third is obturated, a radiograph is made to ensure placement.
- Another obturation method has become popular. A fitted master point is initially placed to the apical terminus, followed by depositing warm gutta-percha around the master point. This technique will better ensure apical closure without overfilling.
- If the filling is short, gutta-percha may be warmed with a hot instrument and then further compacted, or the gutta-percha mass may be completely removed and the canal re-filled. In this event, the tip of a Hedström file is warmed and inserted into the mass. After cooling, for 1 minute, it is removed with the gutta-percha bolus.

Compaction is necessary to close space and gaps while forcing the gutta-percha laterally and vertically. It also compensates for shrinkage as the gutta-percha cools. Furthermore, the smallest injection needle, 23-gauge, is too large to reach the apex in most cases. Compaction must be done, however, as soon as the softened gutta-percha is placed in the canal because it cools

rapidly and hardens, often within 1 minute.

Indications

- Roots with straight or slightly curved canals.
- Backfilling of canals.
- Obturation of roots with fins, accessory canals, C-shaped canals, internal resorption or perforations….etc.

Fig. 14. The Obtura III system.

Disadvantages

Although the heat generated by this method was found to be safe (gutta-percha merged from the needle at 71.2°C), serious overfilling and apical extrusions may occur.

• *Ultrafil 3D System:*

This system depends upon using alpha-phase gutta-percha supplied in disposable cannules with 22-gauge needle attached. The gutta-percha in these cannules becomes plasticized then warmed to 70°C in a special heater. The warmed cannules are then placed in a special pistol-grip syringe for injection into the canal.

The cannules are supplied in three different viscosities:

- Endo Fil-Regular (white cannule), light-bodied – sets in 30 minutes.
- Endo Set (green cannule), heavy-bodied, high-viscosity – sets in 2 minutes
- Firm Set (blue cannule), less viscosity – sets in 4 minutes.

Alpha-phase gutta-percha is made by further masticating beta-phase gutta-percha under advancing heat. The longer the mastication continues, the thinner the viscosity becomes when gutta-percha is plasticized. Standard beta-phase gutta-percha has a melting point of 160°C. This is lowered to 70°C in alpha-phase gutta-percha, which also causes it to become much more adhesive, or "tacky" when plasticized. It takes 15 minutes to reach a flowable state in the heater.

For canals to be filled with the Ultrafil 3D system, they need to have:

- Continuously tapered canal large enough, 8-10 mm from the apex, to receive a 22-gauge needle (about the size of file 50).
- Perfect apical stop or else extrusion could occur.

Technique

- After drying the canal, it is lightly coated with sealer, and the needle of the cannule placed in the canal. It must fit loosely without binding, 8 to 10 mm from the apex.
- Working time is 60-70 seconds. The syringe trigger is squeezed and released and, after 3 seconds of wait, squeezed and released again. This sends a bolus of gutta-percha towards the apex.
- The needle is not withdrawn but left in place until a "lift" is felt as the material flows to the apex and backflow tends to displace the needle. Injection is then continued, not forcing the deposit, but allowing the gutta-percha to displace the needle from the canal.
- The regular-set Ultrafil (white cannule) gutta-percha can not be compacted because of soft consistency. Pluggers just punch through the material without displacing. It does not reach full set for 30 minutes.
- The Ultrafil may be used in the presence of master point. The master point is positioned at full working length to block the apical foramen. This point is then moved aside with a cold spreader to make room for the

Ultrafil cannule needle, which is inserted as deep as possible into the canal.

- The Endoset (green cannule), the high viscosity gutta-percha that has less flow, can be compacted with pluggers or spreaders, hence either vertical or lateral compaction can be used. The canal walls are first coated with sealer; two squeezes of the heavy-bodied Endoset are then injected into the canal at the 8 to 10 mm level from the apex. It is immediately compacted apically and laterally with the fitted plugger, which must be dipped in alcohol to prevent its sticking to tacky gutta-percha.
- When apical filling is radiographically confirmed, the remainder of the canal is segmentally filled with Endoset, each segment compacted with increasingly larger pluggers. This is essentially the warm vertical compaction technique and has an advantage over the less viscous Ultrafil compaction of warm gutta-percha, thus negating in part the tendency to shrink on cooling (Fig. 15).

Fig. 15. The Ultrafil 3D system.

Indications

Owing to the flow characteristics of the light-bodied Endofil-regular (white cannule) or Firmset (blue cannule), broken instruments may be bypassed and internal resorptive defects filled.

Disadvantages

- Extrusion through the apical foramen.

The Elements Obturation Unit (Sybron Endo)

The Elements system (Fig. 16) combines a System B device and a gutta-percha extruder in a motorized handpiece to make obturation efficient, predictable, and accurate. From downpack to backfill, the Elements Obturation Unit puts the continuous wave of condensation technique into one simple-to-operate device. The extruder tips are sized 20-, 23-, and 25-gauge and are prebent.

System B forms the right portion of the system, with functions preset for temperature and duration. The tip temperature is continuously maintained and displayed, and the system has a time-out feature that prevents overheating. Extruder forms the left portion of the system, which is a handpiece for gutta-percha delivery. It consists of a precise temperature control in a motorized handpiece that eliminates hand fatigue and precludes voids. Both the handpieces have a silicon booting that serves as an insulator to avoid heat conduction to the clinician's hands during its operation.

Fig. 16. The Elements obturation unit.

VI. Solid-core carrier:

• *Thermafil:*

Thermafil and Densfil consist of thermo-plasticized alpha-phase gutta-percha carried into the canal on a solid core. Thermafil is an endodontic obturator consisting of a flexible central carrier sized and tapered to match standard endodontic files that are uniformly coated with a layer of refined and tested alpha-phase gutta-percha. The carriers are made of titanium or radioopaque plastic. The gutta-percha covering the metal carriers may be heated on a flame. However, the plastic core-carrier obturators can only be heated in a special oven called *Thermaprep*. Actually, it is recommended that all core-styles of obturators be heated in the oven from 3 to 7 minutes depending on the size that ranges from size 20 through size 140. The gutta-percha coating extends beyond the length of the carrier by 1-2 mm.

Technique

- To select Thermafil obturator of the size and shape of the canal, verify the length of verifier reaching passively to the working length by taking a radiograph.
- After canal preparation and drying, a very light coat of sealer is applied to all the walls to act as an adhesive and a lubricant. Sealers such as Thermaseal, AH plus, Sealapex and zinc oxide and eugenol-based sealers should be used. Sealers such as CRCS or Tubliseal, however, should be avoided because they set too quickly when warmed.
- The warmed obturator is removed from the Thermaprep heater slowly carried to full working length in the canal with firm apical pressure. Working time is 8-10 seconds after obturator removal from the oven.
- Once it is radiographically ensured that the obturator has totally filled the canal, the shaft is severed 2 mm above the coronal orifice using an inverted-cone bur in a high-speed handpiece while stabilizing the carrier with index finger.
- Regular gutta-percha cones may be used to fill the canal around the central carrier.
- If a post is to be placed, the Thermafil carrier may be scored at the break-off point, 4 to 5 mm from the apex. It is then twisted off counter clockwise after the obturator fully reaches the apex (Fig. 17).

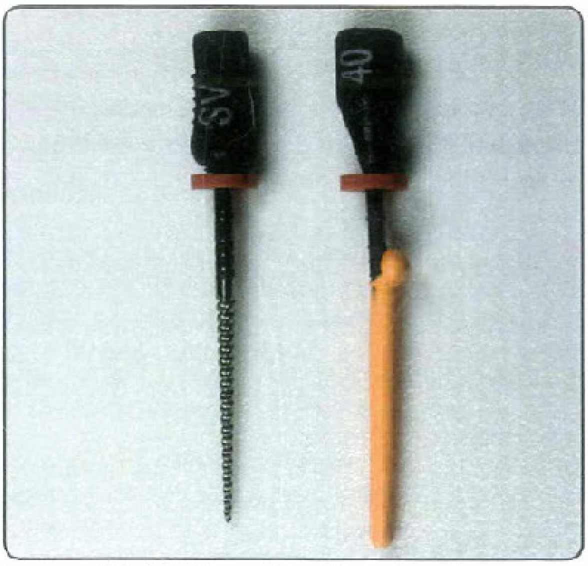


Fig. 17. Thermafil verifier and carrier.

Advantages

- Less chair time.
- Since this technique requires minimum compaction, so less strain occurs during obturation with this technique.

• *SuccessFil:*

The SuccessFil system is also a solid-core carrier coated with alpha-phase gutta-percha. However, the gutta-percha is added to the carrier, in a warm plasticized state, just before it is inserted in the canal.

SuccessFil syringes contain high-viscosity gutta percha that sets in 2 minutes. SuccessFil core carriers are supplied in either titanium or radioopaque plastic. They are inserted into the gutta-percha in the syringe to the measured depth and then extruded by forcing the plunger. Rapid withdrawal creates a tapered shape to the coating gutta percha. Slower withdrawal creates

a cylindrical shape.

Technique

- A SuccessFil core, the same size as the last apical file, is selected and tested for size in the canal. It should go fully to length without binding.
- The carrier is then coated with gutta-percha as described before and is immediately inserted to the full depth without twisting.
- With a vertical plugger (dipped in alcohol), the gutta-percha is better compacted around the carrier.
- After radiographic confirmation, the carrier is separated by holding the handle and reversing the core shaft 2 mm above the orifice.

• *SimpliFill*

SimpliFill (SybronEndo) is gutta-percha or Resilon manufactured for use after canal preparation with LightSpeed instruments (Fig. 18). The carrier has an apical plug with 5 mm of gutta-percha. The technique involves fitting a carrier that is consistent with the master apical rotary file (SybronEndo) to within 1 to 3 mm of the prepared length. Once the cone is fitted it is withdrawn and sealer is applied to the canal walls. AH Plus is recommended. The SimpliFill carrier is slowly advanced to the prepared length. This may require firm pressure. With the plug at the corrected working length the handle is quickly rotated a minimum of four complete terms in a counterclockwise direction to separate the shaft from the apical gutta percha. The coronal space can then be filled with gutta-percha, using lateral compaction or the warm thermoplastic technique. When using lateral compaction, it is recommended that the first cone be the same size as the SimpliFill carrier. This sectional technique is efficient, and leakage potential is similar to that of other common techniques.

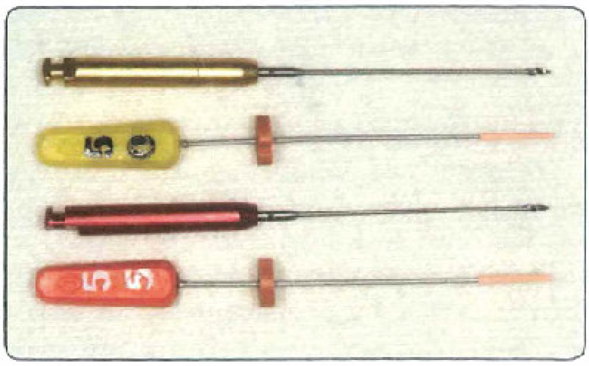


Fig. 18. SimpliFill and LightSpeed instrument.

Immediate obturation

Apical barriers may be necessary in cases with immature apical development, cases with external apical root resorption, and cases where instrumentation extends beyond the confines of the root. Dentin chips, calcium hydroxide, demineralized dentin, lyophilized bone, tricalcium phosphate, hydroxyapatite, and collagen have been used for placement as a barrier in canals exhibiting an open apex. The barriers allow obturation without extrusion of materials into the periradicular tissues but are often incomplete and do not seal the canal. Dentin chips appear to confine materials to the canal space during instrumentation/obturation and may encourage development of a biologic seal. Calcium hydroxide has, also, been extensively used as a common apical barrier. Calcium hydroxide has been shown to induce an apical barrier in apexification procedures; however, the prolonged use of calcium hydroxide may render teeth more susceptible to fracture.

Immature teeth exhibiting pulp necrosis or teeth with apical resorption were traditionally treated with calcium hydroxide to establish an apical barrier (apexification) before obturation. Studies have demonstrated that teeth treated with calcium hydroxide for prolonged periods are more susceptible to fracture. Immediate obturation is an alternative to apexification. An apical barrier material should confine obturation materials to the canal space and enhance healing by inducing cementum and bone formation.

Mineral trioxide aggregate (MTA) (Fig. 19) has been successfully employed as an apical barrier material before obturation. If the material is overextended, it can be easily irrigated out with sterile saline. Mineral trioxide aggregate is sterile, biocompatible, and capable of inducing hard tissue formation. The technique has been shown to be clinically successful and can be accomplished quickly, eliminating the need for numerous patient visits and possible coronal recontamination during the many months required for apexification.

Fig. 19. Mineral trioxide aggregate.

Biodentine (Septodont, Saint Maurdes Fossés, France) is a fast-setting tricalcium silicate–based restorative material with biocompatibility similar to that of MTA. Compared to MTA, Biodentine has considerably shorter setting time and is easier to handle, making it a material worth considering when repairing resorptive defects.

Postobturation instructions and recall

The patient should be advised that the tooth might be slightly tender for few days. For relief of pain, NSAID and warm rinsing are advised. Anti-inflammatory drugs and antibiotics should be prescribed in severe cases. The patient is advised not to chew unduly on the treated tooth until it is protected by a permanent restoration.

The patient should be recalled regularly to evaluate tissue repair and healing progress.

In case of periapical radiolucency, radiographs should be taken at 3,6 and 9 months intervals to see continued new bone formation.

Chapter review Questions

1. What is the appropriate extent of obturation?
2. Mention the different types of core obturation materials.
3. Mention the different types of coated gutta percha.
4. What are the different types of resin-based sealers?
5. What are the different types of monoblocks?
6. Write short notes on:
   - GuttaFlow - SimpliFill
   - Biodentine - Ultrafil 3D

References

- Baumgardner KR, Krell KV. Ultrasonic condensation of gutta-percha: an in vitro dye penetration and scanning electron microscopic study. J Endod 1990, 16:253-9.
- Borges RP, Sousa-Neto MD, Versiani MA, Rached-Júnior FA, De-Deus G, Miranda CE, Pecora JD Changes in the surface of four calcium silicate containing endodontic materials and an epoxy resin based sealer after a solubility test. Int Endod J 2012; 45:419-28.
- Bouillaguet S, Wataha JC, Tay FR, Brackett MG. Lockwood PE Initial in vitro biological response to contemporary endodontic sealers. J Endod 2006; 32:989 92.
- Grossman L. Endodontics. 11th ed. Lea & Febiger, Philadelphia, 1988.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 11th ed. Mosby El Sevier, 2016.
- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 5. 6th ed. BC Decker Inc., 2008
- Jain P Current Therapy in Endodontics. 1st ed. John Wiley & Sons Inc., 2016.
- Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review. I Chemical, physical, and antibacterial properties. J Endod 2010; 36:16-27.
- Parirokh M, Torabinejad M Mineral trioxide aggregate: a comprehensive literature review. III. Clinical applications, drawbacks, and mechanism of action. J Endod 2010; 36: 400-13.
- Pitts DL. Jones JE, Oswald RJ A histological comparison of calcium hydroxide plugs and dentin plugs used for the control of gutta-percha root canal filling material. J Endod 1984; 10:283-93.
- Santos MD, Walker WA, III, Carnes DL. Jr. Evaluation of apical seal in straight canals after obturation using the Lightspeed sectional method. J Endod 1999,25: 609-12.
- Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. J Endod 2007; 33: 391 8
- Tay FR, Pashley DH, Rueggeberg FA, Loushine RJ, Weller RN. Calcium phosphate phase transformation produced by the interaction of the portland cement component of white mineral trioxide aggregate with a phosphate-containing fluid J Endod 2007; 33:1347-51.
- Torabinejad M, Handysides R, Khademi AA, Backland LK. Clinical implications of the smear layer in endodontics: A review. Oral Sug Oral Med Oral Pathol Oral Radiol Endod 2002; 94: 658-66

15 Endodontics Mishaps

Abeer Marzouk

Intended Learning objectives

After reading this chapter, the student should be able to

- Definition of mishaps.
- List the signs and symptoms accompanied by each mishap.
- Recognize causes and prevention of mishaps.
- Summarize the treatment of mishaps.
- Outline the prognosis of each mishap.
- Masters degree students should be able to:
- Investigate the causes and the prevention of these mishaps.
- Classify different mishaps.
- Correlate the effect of different mishaps on the outcome of treatment and evaluate prognosis.
- Detect and differentiate between inaccessible mishaps.
- Select the proper line of treatment.
- Ph.D students should be able to :
- Decide the treatment plan for each mishap selecting the most suitable devices to be used, if needed.
- Correlate the effect of some mishaps on the subsequent steps of treatment.

Chapter Outline

1. **Access related mishaps**
   a. Treating the wrong tooth
   b. Under extended access cavity
   c. Missed canals
   d. Compromised integrity of the existing restoration
   e. Pulp chamber perforation
   f. Crown/root fractures
2. **Instrumentation related mishaps**
   a. Over preparation
   b. Over instrumentation
   c. Ledge formation
   d. Perforations
   e. Separated instruments
   f. Canal blockage
3. **Obturation related mishaps**
   a. Over and under extended root canal fillings.
   b. Vertical root fractures
   c. Nerve paraesthesia
   d. Post space perforation
4. **Miscellaneous mishaps**
   a. Hypochlorite accident
   b. Tissue emphysema
   c. Instrument aspiration and ingestion

Mishaps can be defined as any deviation from accepted standards of care. Those unfortunate iatrogenic occurrences that happen during treatment, some due to inattention to details, while others are totally unpredictable.

The components to consider in the management of endodontic mishaps are:

1. Causes and prevention: depend on knowledge, experience, and learning from own and others' mistakes.
2. Detection: through clinical observation, radiographic examination and patient complain.
3. Correction: depends on the type and severity of accident.
4. Prognosis: re-evaluation of the prognosis of a tooth involved in an endodontic mishap may affect the entire treatment plan.

The following suggestions are helpful in avoiding problems with the patient:

1. Inform the patient before starting, about possible risks involved in the treatment.
2. If a procedural accident occurs, tell the patient the nature of the mishap.
3. If the procedural accident leads to a situation that is beyond your training and level of ability to handle, you should refer to a specialist.

Types of endodontic mishaps

I. Access related mishaps.
II. Instrumentation related mishaps.
III. Obturation related mishaps.
IV. Miscellaneous mishaps.

I. Access related mishaps:

1) Treating the wrong tooth:

• Causes and prevention:

- Inattention of dentist during tooth isolation.
- Misdiagnosis, as in cases with referred pain.
- Mistakes in diagnosis can be prevented or reduced by attention to details and obtaining as much information as possible before deciding a definitive diagnosis. Once a correct diagnosis has been reached, the embarrassing situation of opening the wrong tooth can be prevented by marking the tooth to be treated before isolation with a rubber dam.

• Detection:

- The patient will continue to have symptoms after treatment, when the error is, misdiagnosis.
- The error may be detected after removal of the rubber dam, when the tooth adjacent to the one to be treated was accidentally opened.

• Correction:

- Appropriate treatment of both teeth, the one incorrectly opened and the one with the original problem.
- Even if embarrassing, the safest approach is to explain to the patient what happened and how can the problem be corrected.

2) Under extended access cavity:

• Causes and prevention:

- Poor access placement and inadequate extension of the walls.
- Lack of knowledge of external and internal anatomy of the tooth which causes failure to determine correctly the position of the pulp chamber and the angulation of the bur.
- Failure to remove the roof of the pulp chamber is a serious under extension error, where the pulp horns are mistaken for canal orifices. Fig. (1a,b)
- Information about the location and vertical depth of the pulp chamber obtained through evaluation of pre-operative bite-wing radiograph, together with previous knowledge of the position and number of main and extra root canals, will increasingly reduce this error. All developmental grooves must be traced to their termination and must not be allowed to disappear into an axial wall. Fig. (1c)

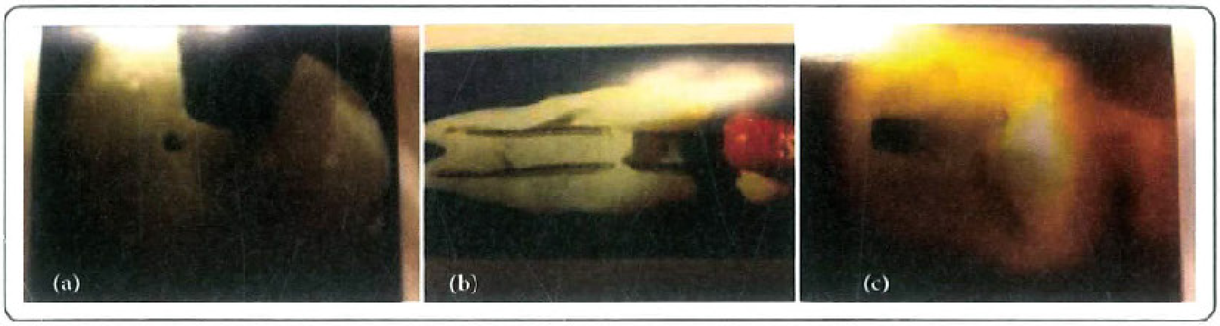


Fig. 1. Pulp horns mistaken for canal orifices, (a) C.S. view, (b) L.S view, (c) Developmental grooves traced to their termination

• Detection:

- The whitish color of the roof, the depth of the access cavity and the lack of developmental grooves are clues for under extension.
- Underextended cavity may lead to a missed canal that causes symptoms to continue.

• Prognosis:

Underextended cavity will considerably decrease the prognosis due to inaccessibility for proper cleaning, shaping and obturation or possibility of missed canal.

• Correction:

- Proper lateral and vertical extensions of the cavity walls should be done to expose all root canal orifices.
- Resulting errors in root canal instrumentation and obturation should be treated if possible, as will be mentioned later.

3) Missed canals:

• Causes and prevention:

- Lack of knowledge about root canal anatomy and extra canals.
- Failure to adequately search for extra canals.
- Improper access cavity preparation.
- Some root canals are inaccessible or readily apparent from the chamber, second mesio-buccal canals in mesial root of maxillary molars are good examples of such canals that are left untreated.

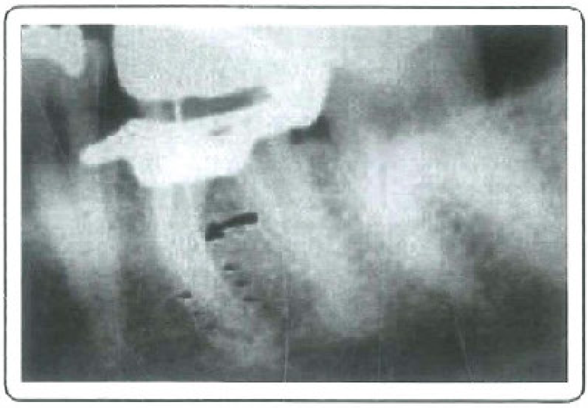


Fig. 2. Instrument deviated to one side indicates the presence of missed canal

- Treating those teeth as having extra canal from the start, unless proven otherwise, is a sure preventive measure.

• Detection:

It could occur during one of the three phases of treatment: early, late or during re-treatment.

- Early and late recognition can be detected radiographically, when an instrument or a filling material do not appear to be exactly centered in the root canal. Fig. (2)
- In some cases, recognition will occur due to patient's complain or until failure is detected on re-call evaluation.

• Prognosis:

- A missed canal decreases the prognosis considerably.
- A slightly better prognosis is expected in roots with 2 canals opening with a single foramen,providing that the primary canal is thoroughly cleaned and filled.

• Correction:

Once the missed canal is detected and located, it should be thoroughly cleaned and obturated.

4) Compromised integrity of existing restoration

• Causes and prevention:

An existing porcelain crown could be chipped, fractured or produce a damaged margin during:

- Preparation of an access cavity through the porcelain crown.
- Placing the rubber dam clamp directly on the margin of a porcelain crown.
- Removal of a permanently cemented crown.
- There is usually no way of predicting if such a mishap is likely to occur. Identifying those procedures that may cause damage to the restoration should prepare the dentist to exercise caution during their performance.

• Correction:

The best policy is to routinely inform the patient that crown damage may occur either if:

- There is a risk that the restoration may even need replacement. Or
- minor chipping can be repaired by bonding composite resin to the crown.

5) Pulp chamber perforation:

It is an undesirable communication between pulp space and the external tooth surface, it could occur in the pulp chamber wall or floor Fig. (3a,b).

• Causes and prevention:

- Failure to properly establish the floor depth of pulp chamber lead to furcal perforation in molars and premolars.
- Failure to recognize severely tilted teeth causes perforations into the sulcus and periodontal space.
- Improper direction of the bur to be parallel to the long axis of the tooth. Fig. (3c)

Prevention of this procedural mishap is best accomplished by close attention to the principles of access cavity preparation, having adequate size and correct location. Careful attention to radiographic information can also guide the dentist.

• Detection:

- Direct observation of bleeding.
- Indirect bleeding using paper point.
- Radiographical examination.

• Prognosis:

The corrective option and the effects on prognosis will vary depending on:

- Perforation size: small size perforations have better prognosis than large size ones.
- Perforation location: perforation coronal to the level of crestal bone and epithelial attachment with no damage to supporting tissues and easy access has good prognosis. Crestal perforation at the level of eipthelial attachment has a questionable prognosis. Perforation in the furcal region of molars are particularly challenging depending on time of repair, size of perforation and risk of extrusion of the filling material into periodontal tissues which may impair desirable healing.

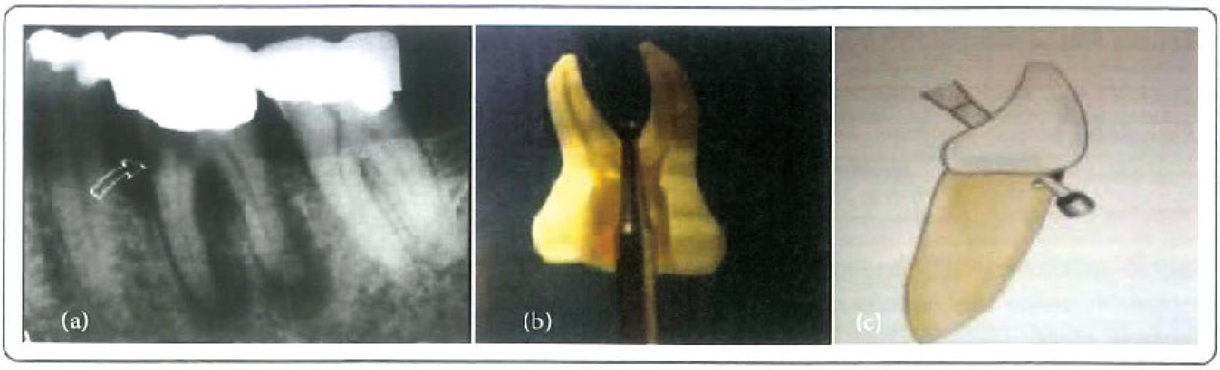


Fig. 3. (a) Pulp chamber wall perforation, (b) Pulp chamber floor perforation, (c) Perforation due to improper direction of the bur.

- Existing periodontal condition: perforation may cause a periodontal pocket that may undergo minimal long term deterioration, with proper hygiene.
- Early detection: has significant effect on prognosis .The less time the perforation is open to contamination, the better the prognosis.
- Sealing the perforation: proper sealing to prevent leakage improves prognosis. Perforation in the floor of the chamber may develop a lesion in the furcation that will have better prognosis by proper sealing of the perforation as soon as possible.

• Correction:

- After cleaning and disinfecting the defect, controlling bleeding and fluid seepage, repair can be accomplished by sealing the perforation site with a suitable material as will be discussed later.
- The type of material used is properly less important than how well the perforation sealed.

6) Crown root fractures:

• Causes and prevention:

- An endodontically treated tooth, weakened by access cavity preparation, with a pre-existing infraction may suffer a true fracture during chewing. Fig. (4a,b)
- Vertical fracture of endodontically treated teeth is a complication that can be reduced by avoiding over extension of the access cavity and reduction of the occlusal surface before working length is established.

• Detection:

- Mobility of portion of the crown will be obvious.
- Patient complain due to the development of a periodontal lesion.

• Prognosis:

Teeth with a chisel fracture have better prognosis than those with more extended fracture.

• Correction:

- Teeth with a chisel fracture in which only the cusp or part of the crown is involved, could be treated by removal of the loose segment and restored.
- Teeth with extensive vertical fracture should be extracted.

II Instrumentation related mishaps:

1) Over preparation:

• Causes and prevention:

-It is due to excessive removal of tooth structure during radicular preparation, in the apical, middle or coronal portions of the root canal . This leads to:

* Overzealous shaping to accommodate large plugger or/ and spreader. Fig. (5a)
* Over flaring.

- Fulfilling objectives of radicular cavity preparation, with maintenance of the original shape and curvature of root canal are measures to avoid such mishap.

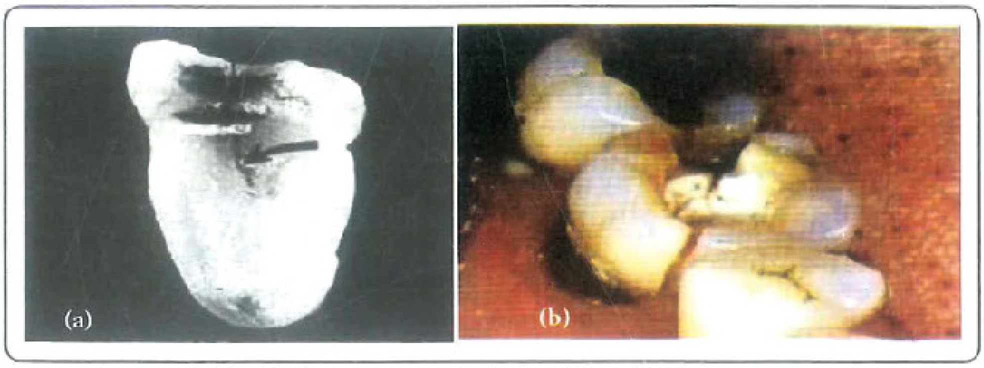


Fig. 4. Crown root fracture (a) L.S. view, (b) C.S. view

• Prognosis:

- Teeth suffering over-zealous shaping may be weakened to a point of apical fracture.
- Over-flaring leads to:
    * Strip perforation at the inner thin wall of the curve (dangerous zone). Fig. (5b).
    * Weakening of the tooth to a point that leads to a vertical root fracture.
    * Difficulty to fit parallel posts.

2) Over instrumentation:

• Causes and prevention:

- Instrumentation beyond apical constriction is due to improper tooth length determination.
- Confining cleaning and shaping procedure within the root canal reduces the mishap.

• Detection:

- Hemorrhage is evident apically and could be detected by paper point insertion. Fig. (6a).
- Radiograph will show evidence of apical constriction violation by a large file, a master cone or over extended filling.Fig. (6b).
- Tactile resistance of the confines of the canal wall is lost.

• Prognosis:

Teeth suffering loss of apical constriction will have poor prognosis as a result of irritation of periapical tissues during instrumentation and after treatment due to risk of overfilling and inadequate apical seal.

• Correction:

Violated apical constriction is treated by re-establishment of working length, followed by enlargement of the canal with larger instruments to the new length to create a new apical stop.

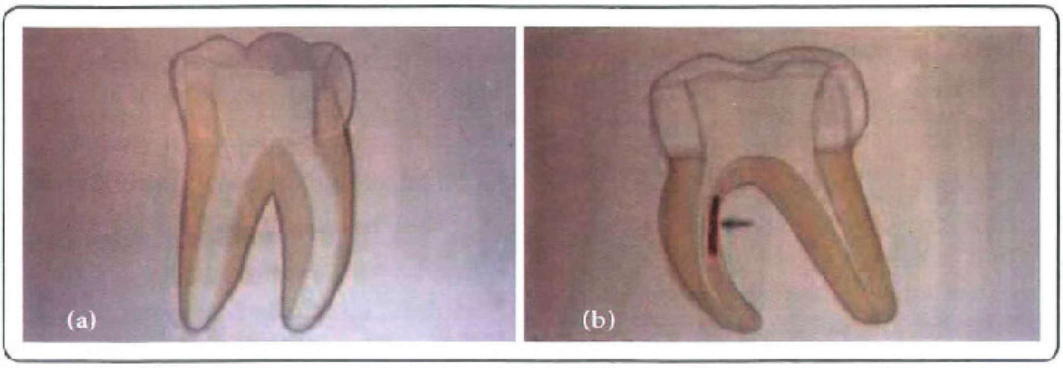


Fig. 5. (a) Overzealous shaping, (b) Strip perforation in the inner thin wall of the root canal curve

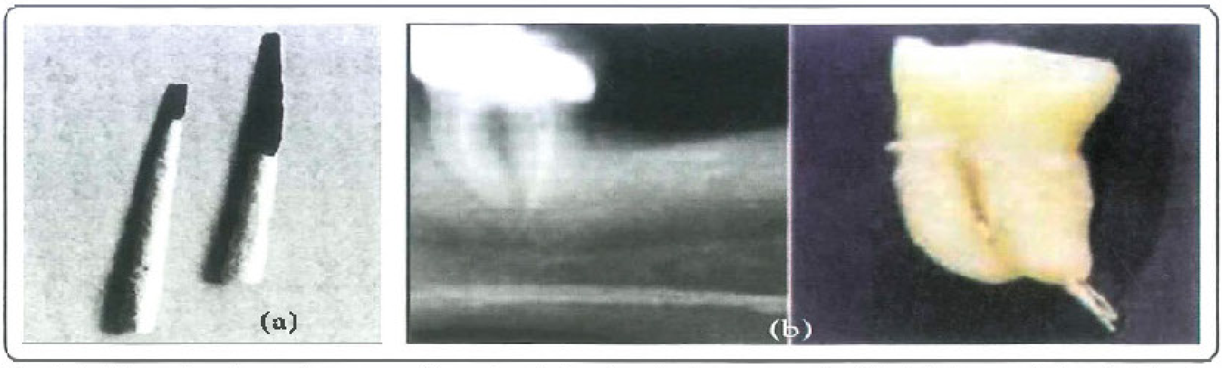


Fig. 6. (a) Detecting of over instrumentation and apical perforation by paper point, (b) Apical constriction violation by a large file or over extended filling

3) Ledge formation:

• Causes and prevention:

A file fails to negotiate a canal curvature and reach the exact working length, due to:

- Failure to make a proper access cavity and coronal canal pre-flare, that allow direct access to the apical portion of the canal.
- Using straight or too large instruments in curved canals.
- Lack of knowledge of canal morphology that enables the dentist to detect root curvature that does not show on the radiograph.
- Avoiding these causes, together with using pre curved instruments having non-cutting tip, will reduce this problem, as this allows files to track the lumen of the canal. Accurate interpretation of diagnostic and working length radiogragh is also essential.

• Detection:

- Instruments inserted in the ledged root canal can no longer reach full working length.
- Instrument tip hits loosely against a solid wall, with no tactile sensation of binding.
- Radiogragh shows inability of the inserted instruments to reach the full working length.

• Prognosis:

Root canals where ledges are by-passed have excellent prognosis if the rest of the treatment procedures are properly done. Failure to by pass the ledge will leave an uninstrumented apical portion of the canal, which will cause future complications.

• Correction:

- A small file with a sharp curvature at its tip is inserted in the canal.
- The curved tip should be pointed towards the wall opposite to the ledge Fig. (7).

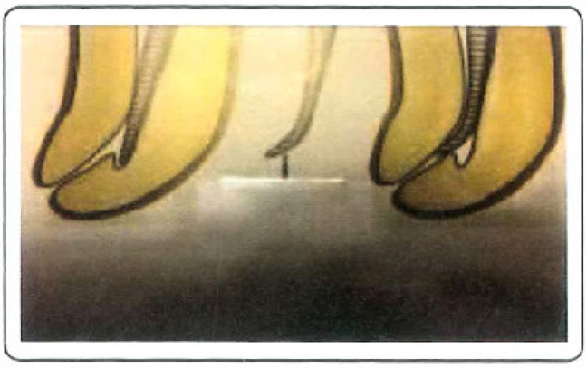


Fig. 7. Ledge correction

- Introduce the file with a watch winding motion that will help advance the instrument.
- When a resistance is met, the file is slightly retracted, rotated and introduced again until it bypasses the ledge and reach the full working length.
- Larger files are used in the same manner successively.
- When the files reach the apex, filing is done, in the presence of an irrigant, in short vertical strokes with the file curved tip directed towards the inner wall of the curve and pressing its blades against the ledge in the outer wall of the canal.
- Using chelating agent as ETDA is not advised as it enhances perforation.

4) Perforation:

Perforation in the root canal may occur in the cervical, middle or apical thirds.

• Causes and prevention:

Cervical perforation: Fig. (8a)

- It may occur during the process of locating canal orifices.
- Overflaring may also lead to strip perforation.
- Prevention of cervical perforation may be achieved by reviewing tooth morphology prior to access cavity and searching for canal orifices. Also radiographically verifying ones

position during the search get the operator back on track before it is too late.

Mid-root perforation: Fig. (8b)

- Failure to correct a ledge at mid root portion and continue to drill the instrument out through the lateral wall of the root canal at the point of obstruction or curvature leading to a lateral perforation.
- Over flaring resulting in a strip perforation.
- Anti-curvature filing is used to overcome this problem, where the operator applies mesial pressure on the enlarging instrument to avoid the thin, delicate distal wall (dangerous zone).

Apical root perforation: Fig. (8c)

- Failure to correct a ledge in the apical root portion.
- Apical transportation due to over instrumentation.
- Apical zipping due to the use of large and straight instruments in preparing the apical root third.

• Detection:

Perforation at any level of the root canal can be detected by:

- Patient's sudden complaint of pain during canal preparation.
- Sudden appearance of blood in a previously dry canal.
- Paper point inserted in the canal will confirm a suspected perforation corresponding to its level.
- Radiographic evidence of a file, protruding through the lateral wall or apical constriction of the canal.
- Loss of the tactile resistance of the confines of the canal space is detected, only in apical perforation.

• Prognosis:

Apical perforation usually occurs more than cervical and mid-root perforations. Fortunately, with successful repair, apical perforations have less adverse effect on prognosis than the other types.

• Correction:

- Although the more apical the perforation is the more favorable the prognosis, the converse is true for the repair procedure. The more coronal the perforation is where it is considered to be more accessible, the easier is to repair.
- Perforation repair may be done non-surgically by approaching the defect internally through the root canal space or surgically by using an external approach through the periradicular tissues. The choice depends on the accessibility of the defect.
- Non-surgical perforation repair is the preferred method because (1) it is less invasive (2) produces less destruction to the periradicular tissues (3) improves isolation from microbes.

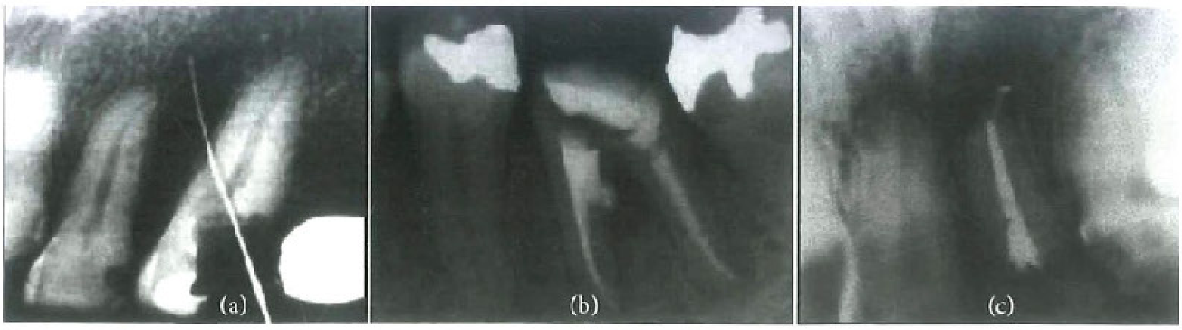


Fig. 8. (a) Cervical root perforation, (b) Mid-root perforation, (c) Apical root perforation

- Commonly used perforation materials include amalgam, Super EBA cement, various bonded composite materials and most recently mineral trioxide aggregate (MTA).
- MTA has many advantages over other perforation repair materials: (1) it seals well even when the cavity is contaminated with blood (2) it is very biocompatible (3) it activates a cementum-like material to grow directly on it after placement and (4) it has a high degree of clinically favorable long term out-comes when used as a perforation repair material.
- The main disadvantage of MTA is the long setting time, which makes the material not suitable for repair of defects in communication with the oral fluids as it will be washed out of the defect before setting.
- Enhanced vision in non-surgical repair of perforation deeper in the canal could be provided by the use of surgical operating microscope.
- Perforation in the apical portion is the most difficult to repair because repair not only involves cleaning and sealing the defect, but also involving, cleaning and filling the apical canal segment beyond the defect. Surgical approach might be the only choice.

5) Separated Instruments:

• Causes and prevention:

Breakage is common in both hand and rotary stressed instruments which is due to:

- Improper convenience of access cavity.
- Placing exaggerated bends on instruments to negotiate curved canals.
- Forcing a large file down the canal before this canal is sufficiently enlarged with a previous smaller file.
- Excessive rotation of the instrument in a canal after binding.
- Manufacture defects.

Such a mishap could be avoided by examining the instrument for signs of stress before use. A stressed instrument is recognized by unwound flutes and should be discarded Fig. (9a). Small instruments used to enlarge difficult, small and curved canals should be discarded, even after a single use. Discarding of rotary instruments should follow manufacturer's instructions for number of times of use.

- Sequential instrumentation and use of irrigation are also essential measures for reducing this error.

• Detection:

Sudden loss of working length during instrumentation with radiographic evidence of lodged instrument segment inside the canal Fig. (9b), confirmed by the broken instrument in the operator's hand.

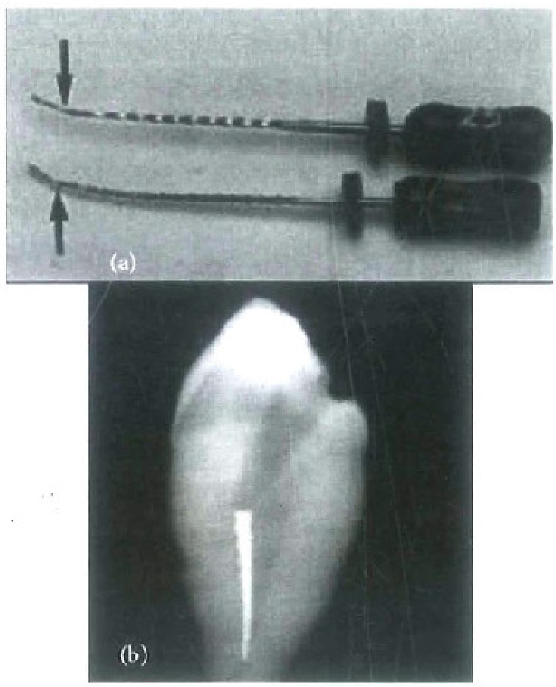


Fig. 9. (a) Stressed instrument with unwound flutes, (b) A radiograph showing a separated instrument lodged inside the middle portion of the canal

• Prognosis:

It is not affected in case the instrument is removed or by-passed. If surgery is needed prognosis is reduced according to the outcome of the treatment.

• Correction:

- Efforts to remove instrument fragments should be made as initial approach. Ultrasonic instruments have proven to be most effective in loosening and flushing out broken fragments, especially under operating microscope.
- Failing to remove the broken fragment, an attempt to by-pass it by a small file or reamer should be tried. This is usually successful in oval or irregular canals where the broken segment is stuck between the irregularities of the wall.
- Failing to by-pass the broken segment, preparing and filling the canal should be done to the level that could be reached:

  • If the segment is at the exact working length and not protruding through the apex, it should be considered part of the filling and help to seal the canal.

  • If the segment is protruded through the apex or leaving an un-instrumented apical portion of the canal, apical surgery will be the treatment of choice.

6) Canal blockage:

Blockage is obstruction in a previously patent canal that prevents access to the apical constriction and apical stop.

• Causes and prevention:

- Packed dentinal chips and debris as hard mass.
- Compacted vital pulp tissues as fibrous blockage.
- Cotton pellets, restorative materials and fractured instruments also present blockage.
- Frequent irrigation and maintaining patency reduce such a mishap.

• Detection:

The confirmed working length is no longer attained.

• Prognosis:

Depends on the stage of instrumentation reached when blockage occurs and pulp vitality.

- Blockage occurring in an adequately cleaned canal has better prognosis than blockage occurring before the canal is cleaned.
- Teeth with vital pulp have better prognosis than those with necrotic pulp.

• Correction:

Recapitulation with the smallest file should be done, using a small amount of chelating agent, watch winding motion and copious amount of irrigation.

III Obturation related mishaps:

1) Over and under extended root canal fillings:

• Causes and prevention:

- Over extended filling is due to apical perforation with loss of apical constriction against which gutta-percha is compacted. Fig. (10a).
- Under extended filling is due to failure to fit the master cone accurately or poorly prepared canal, particularly in the apical portion. Fig. (10b).
- Accurate working length determination and care to maintain it, together with taking radiograph during the initial phases of obturation will very much reduce both over and under fillings.
- Creating an apical barrier in case of wide apical foramen or apical resorption is essential to avoid over extended filling.

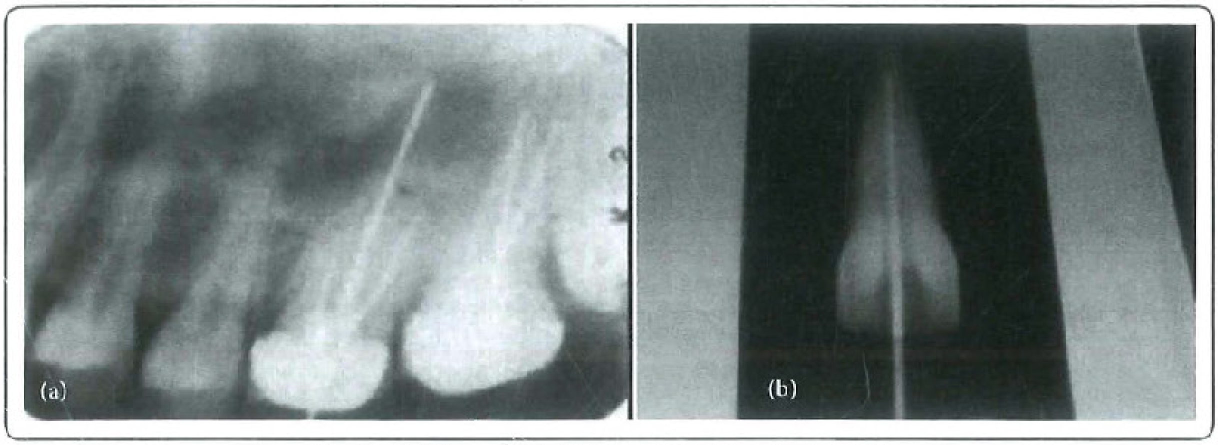


Fig. 10. (a) Over extended filling, (b) Under extended filling

• Detection:

A post operative radiograph will show any error in the extension of the filling material.

• Prognosis:

- Failure may be less from irritation of the filling material and more from leakage around a poorly compacted filling. Success is determined by the quality of the apical seal. So if the over extended filling provides an adequate seal, treatment may still be successful.
- Failure in under extended filling cases is due to the apical root canal segment that remains unfilled allowing re-entrance of micro-organisms in the root canal, causing persistence of an already existing lesion or developing a new one.

• Correction:

- Under extended filling is treated by removal of the filling material, properly preparing and obturating the canal in three dimensions.

  Over extended fillings do not routinely require removal if asymptomatic and not associated with a lesion, as guttapercha and lots of recent sealers are well tolerated by the surrounding tissues.
- If symptoms or radicular lesion develop the over extended filling should be removed either:
  - o Successfully with the entire point pulled out in one piece or
  - o The point will tear off, leaving a loose fragment in the periradicular tissue that will need surgical removal.

2) Vertical root fracture:

• Causes and prevention:

- Exerting too much force during lateral or vertical condensation technique.
- Forcing the post apically during seating and cementation.
- Therefore less forceful obturation techniques and passive seating of the posts should be ensured to reduce such a mishap.

• Detection:

- Sudden crunching or sharp sound.

  Pain reaction.
- Bleeding
- The presence of a very narrow periodontal pocket along the fracture line.
- Halo radiolucency may appear in the radiograph of a long standing vertical root fracture.
- Exploring surgery may be needed to confirm the diagnosis.
- Loss of resistance against lateral condensation.

• Correction:

- Unfortunately, extraction is the only treatment plan in such case.
- In multirooted teeth root resection or hemisection.

3) Nerve paresthesia:

• Causes and prevention:

- Gross over extension of root canal filling materials. Fomaldehyde containing sealers have the highest incidence of nerve toxicity. Fig. (11).

Fig. 11. Gross over extension of root canal filling.

- Over instrumentation.
- Surgical procedures.
- The dentist should have proper judge in his selection of cases that need surgery to avoid such a problem. If there is no alternative treatment than surgery in a case where nerve damage is possible to happen, then the patient should be informed of the problem before surgery.

• Detection:

Patient's complaint.

• Prognosis:

Nerve damage may be transient or permanent.

• Correction:

- Often through observation.
- Use of prednisolone to shorten the course of the condition, prevent secondary fibrosis and lessen the severity of postoperative complications.

  Surgical decompression has also been reported.

4) Post space perforation: Fig. (12)

• Causes and Prevention:

- Misdirected post space preparation, especially with the use of end cutting drill or round bur, increases the incidence of lateral root perforation.
- Planning the post space preparation, based on good knowledge of the root canal anatomy and radiographic information will help in reducing incidence of perforation.
- Preparing the space at the time of obturation also reduces the risk.

• Detection, prognosis and correction: as mentioned before, in perforation section.

Fig. 12. Post space perforation

VI. Miscellaneous mishaps:

1) **Hypochlorite accident:** (irrigant related mishaps) Fig. (13).

• Causes and prevention:

- Accidental injection of sodium hypochlorite beyond the apical foramen will lead to this condition which is serious and very painful.
- This accident could be avoided by passive placement of a beveled irrigating needle, that slowly delivers the irrigating solution into the canal, allowing the excess irrigant to flow coronally rather than apically. The use of special irrigating needles such as Goldman's syringe or laterally perforated needles will also help.

Fig. 13. Accidental injection of sodium hypochlorite beyond the apical foramen

• Detection:

Effects on the patient depend on the concentration and amount of solution injected periapically.

- Sudden severe pain.
- Violent swelling.
- Interstitial hemorrhage.
- Ecchymosis.

• Prognosis:

It is favorable, but immediate and proper management with close observation are important.

- Long term effects may include paresthesia, scarring and muscle weakness.

• Correction:

- Reassurance of the patient.
- Antibiotics to prevent spread of infection, if any, related to tissue destruction.
- Analgesics to relief pain.
- Antihistamines can also be helpful, to reduce any allergic reaction.
- Cold application initially, followed by warm saline soaks the next day to reduce swelling.
- Incision and drainage may also be necessary to control swelling and pain.
- In severe cases hospitalization and surgical intervention are essential.

2) Tissue emphysema:

• Causes and prevention:

It is the passage and collection of gases in tissue spaces due to compressed air being forced into these spaces through:

- A blast of air to dry the canal, during canal preparation.
- Air from high speed hand piece directed towards exposed soft tissue, during apical surgery.
- Forceful injection of hydrogen peroxide during irrigation.
- Preventive measures used to avoid this error, includes the use of paper points to dry the canal,but if an air syringe is used, it should be directed in a horizontal position over the access cavity. In surgical procedures, apical root cavity can be made by a low speed hand piece, but if a high speed hand piece is used, jets of air should not be directed into the surgery sites.

• Detection:

- Rapid swelling and erythema.
- Although pain is not uncommon dysphagia and dyspnea have been reported.
- Spread of air into the neck may cause respiratory difficulty and progression into the mediastinum could be fatal. Mediastinal emphysema is detected by:
  - o Sudden swelling of the neck.
  - o Difficulty in breathing and the patient's voice will sound brassy.
  - o Crackling can be induced when the swollen region is palpated.
  - o The mdiastinal crunching voice is heard on auscultation.
  - o Air spaces are seen in anteroposterior and lateral chest radiographs.

• Prognosis:

Tissue space emphysema may remain in the subcutaneous connective tissue and do not spread to the deep anatomic spaces. The majority of reported cases have followed a benign course followed by total recovery. Spread of air into the neck and into the mediastinum reduces prognosis.

• Correction:

- It varies from palliative care and observation, to immediate medical care, if the airway is compromised.
- Broad-spectrum antibiotic coverage is indicated in all cases to prevent the risk of secondary infection.

3) Instrumentation aspiration and ingestion:

• Causes and prevention:

Failure to use a rubber dam during endodontic treatment can easily lead to this mishap. Therefore a rubber dam is mandatory in all phases of endodontic therapy.

• Detection:

May not be recognizable but if noticed, it is confirmed by chest and abdomen radiographs. Fig. (14).

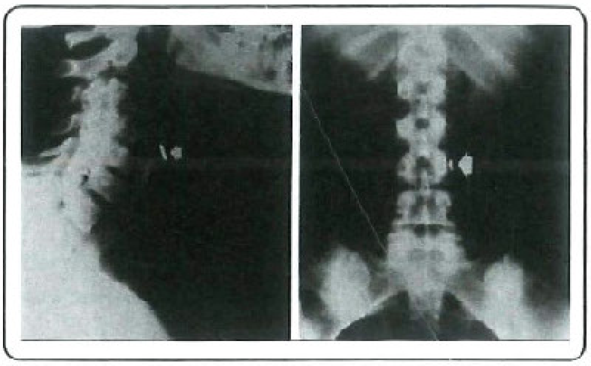


Fig. 14. Radiograph showing an aspirated instrument

- In the dental clinic, the treatment is limited to removal of the objects that are accessible in the throat. Removal can be done by high volume suction, hemostats and cotton pliers.
- In case of aspiration, medical evacuation is the best approach. Sometime the patient may cough out the inspired item.

Chapter review Questions

1. Discuss different corrective options for over and under extended filling.
2. How can a vertical root fracture be detected?
3. Canal blockage is one of the most annoying errors. Discuss different causes for such error and how to correct.
4. Tissue emphysema has several signs and symptoms, discuss and explain how to deal with them.

References

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics. 5th ed. BC Decker Inc ,2002.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Jafarzadeh H, Abbott PV. Ledge formation: review of a great challenge in endodontics. J Endod. 2007 Oct;33(10):1155-62.
- Nevares G, Cunha RS, Zuolo ML, Bueno CE. Success rates for removing or bypassing fractured instruments: a prospective clinical study. J Endod. 2012 Apr;38(4):442-4
- Estrela C, Pécora JD, Estrela CRA, Guedes OA, Silva BSF, Soares CJ, Sosa Neto MD. Common Operative Procedural Errors and Clinical Factors Associated with Root Canal Treatment. Braz Dent J. 2017 Jan-Apr;28(2):179-190.

3
PART

CLINICAL ENDODONTICS

16

Local Anesthesia and Isolation in Endodontics

Heba El Far
Laila M. Kenawi

Intended Learning objectives

After reading this chapter, the student should be able to

1. Recognize the importance (uses) of local anesthesia in endodontics.
2. Recognize the possible adverse effects of local anesthesia.
3. Describe the effect of systemic diseases on local anesthesia.
4. Recognize the maximal allowed dose of local anesthesia.
5. Identify different anesthetic techniques used in the maxilla and the mandible.
6. Recognize factors affecting endodontic anesthesia
7. Describe the initial patient management
8. List the advantages and disadvantages of intrapulpal anesthesia.
9. Describe the supplemental anesthetic techniques used in endodontics.
10. Recognize the recent advances in delivering local anesthesia and the local anesthestic reversal.
11. Describe the different components of rubber dam and their functions.
12. List the advantages and disadvantages of rubber dam isolation in endodontics.
13. Describe the isolation of difficult cases in endodontics.
14. Describe different techniques of rubber dam application.

Chapter Outline

I- Local anesthesia (LA) in endodontics

Regardless of the clinician's skills, endodontic treatment cannot be delivered without effective pain control.

1- Uses of local anesthetics in endodontics :

a) Diagnosis

b) Treatment of emergency patients

c) Development of a comprehensive pain-control plan

2- Most common types of injectable local anesthetics:

- 2% Lidocaine
- 2 or 3% Mepivacaine
- 4% Prilocaine
- 0.5% Bupivacaine
- 4% Articaine

with or without vasoconstrictor(epinephrine)

Although LA can be divided roughly into 3 types according to duration:

- Short duration (30 minutes pulpal anesthesia)
- Intermediate duration (60 minutes)
- Long duration

Yet ...

Clinical anesthesia does not follow these guidelines, depending on whether the local anesthesia is used as a block or for infiltration.

3- Possible adverse effects of a local anesthetic range from fairly common (eg. tachycardia) to extremely rare (eg. allergic reactions to lidcaine)

a) **Cardiovascular reactions:**

Even comparatively small amounts of epinephrine can induce measurable response.

- Tachycardia (increase heart rate) after nerve block or intraosseous injection.
- Heart palpitations (fear and anxiety).
- Change in blood pressure.

Large doses or inadvertent intravenous injection leads to lidocaine toxicity and CNS depression.

To reduce this risk the clinician should:

- Aspirate before making injection.
- Inject slowly
- Use dosage within accepted guidelines

b) **Systemic effects:**

Due to repeated injections (cumulative large dose):

- Initial excitatory phase (muscle twitching, tremors, convulsions).
- Subsequent depressive phase (sedation, hypotension, respiratory arrest).

An acute hypotensive crisis with respiratory failure is due to hypersensitivity to local anesthetic agent.

Maximal local anesthetic dosages:(Rule 25):

According to Failure and Moore (Rule 25) it is safe to use one cartridge of local anesthesia for every 25 pounds of patients weight eg. six cartridges for a patient weighing 150 pounds (67.5 kg).

c) **Methemoglobinemia (overdoasge):**

Methemoglobinemia *is a disorder characterized by the presence of a higher than normal level of methemoglobin (metHb) in the blood. Methemoglobin is an oxidized form of hemoglobin that has a decreased affinity for oxygen, resulting in an increased affinity of oxygen to other heme sites and overall reduced ability to release oxygen to tissues .*

It occurs several hours after injection of local anesthesia .

Signs and symptoms: cyanosis, dyspnea, emesis, headache.

d) **Peripheral nerve paresthesia:**

Rare yet needs follow up.

e) **Reactions of anesthetic formulations containing a sulfite antioxidant:**

Rare in the form of urticaria and bronchospasm.

Local anesthesia containing vasocon strictor contain relatively small amount of sulfite to prevent its oxidation.

Risk factors: Active history of asthma and atopic allergy.

4- **Effects of systemic diseases on L.A:**

a) **Cardiac patients:**

Patients with:

i. History of myocardial infarction or stroke within past 6 months.
ii. Unstable angina pectoris.
iii. Severe hypertension.
iv. Uncontrolled congestive heart failure.
v. Heart transplant.

No vasoconstrictor in L.A.

Consult their physician

b) **Hodgkin's diseases or cancer**

Receiving radiation, use reduced dosage of local anesthesia containing vasoconstrictor.

c) **Pregnant and lactating women**

Eliminate pain by performing endodontic treatment thus reduce the need for systemic medications.

d) **Drug interaction**

May occur with vasoconstrictor in local anesthesia and the patients' medication.

5- **Factors affecting endodontic anesthesia:**

a) **Apprehension and anxiety**

Many endodontic patients are apprehensive or anxious because they fear the unknown and have heard unfavorable stories. This emotion plays a role in their perceptions and also affects how they react to pain.

b) **Fatigue**

Many patients with a toothache have not slept well, not eaten properly, or otherwise have not functioned normally. In addition, many are apprehensive or anxious about the appointment. The end result is a patient with a decreased ability to manage stress and less tolerance for pain.

c) **Tissue inflammation**

Inflamed tissues have a lower threshold of pain perception; this is called the allodynia phenomenon. In other words, a tissue that is inflamed is much more sensitive and reactive to a mild stimulus. Therefore, an inflamed tissue responds painfully to a stimulus that otherwise would go unnoticed or perceived only mildly. Because root canal treatment procedures generally involve inflamed pulpal or periradicular tissues, this phenomenon has obvious importance. A related complication is that inflamed tissues are more difficult to anesthetize.

d) **Previous unsuccessful anesthesia**

Unfortunately, profound pulpal anesthesia is not always obtained with conventional techniques. Previous difficulty with teeth becoming anesthetized is associated with a likelihood of subsequent unsuccessful anesthesia. These patients are likely to be apprehensive (lower pain threshold) and generally identify them selves by comments such as, "Novocain never seems to work very well on me" or "A lot of shots are always necessary to deaden my teeth." The practitioner should anticipate difficulties in obtaining anesthesia in such patients. Often, psychological management and supplemental local anesthesia techniques are required.

6- **Initial management**

If the patient is managed properly and anesthetic techniques are done smoothly, the pain threshold increases. The result is more predictable anesthesia and a less apprehensive, more co operative patient.

❒ **Psychological approach (involves 4 Cs) :**

1- **Control;** obtaining and maintain upper hand.

2- **Communication;** listening and explaining to the patient what is to be done and what should be expected.

3- **Concern;** verbalizing awareness of pt's apprehensions.

4- **Confidence;** expressed in professionalism giving the patient confidence in management, diagnostic and treatment skills of the dentist.

❒ **Painless injection**

a) Use of topical anesthetic:

The most important aspect of a topical local anesthesia may not be its clinical effectiveness but rather its psychologic effect on the patient who believes the practitioner is doing everything possible to prevent pain.

b) *Slow needle insertion.*

c) *Slow injection* (computer controlled anesthetic delivery system, 1.4 ml over a period of 4 min 45 sec.).

d) *Two-stage injection; slow administration of ¼ cartridge under* mucosal surface causes numbness then the remaining of cartridge is deposited to full depth at target site.

7- **When to anesthetize???**

Preferably at each appointment.

Misconceptions

a) **During instrumentation:**

Instruments may be used in canals with necrotic pulp and periradicular lesions painlessly without local anesthesia.

Occasionally, vital tissues may be present in apical third, this inflamed tissue contain nerves. Contacting this vital tissue during instrumentation will cause discomfort to the patient if he is not anesthetized.

b) **During canal length determination:**

The patient may show response if the file reaches beyond the apex. This is not true as the patient may feel pain sometimes when the file is far short of the apex or even few millemeters beyond the apex.

c) **During obturation:**

Due to pressure, small amounts of sealer may be extruded beyond the apex, this may be uncomfortable to the patient.

8- **Methods of confirming pulpal anesthesia**

Traditional methods of confirming anesthesia:

- Questioning the patient.
- Soft tissue testing (numbness and lack of response).
- Beginning treatment.

Are not effective in determining pulpal anesthesia

Before endodontic procedure is started, pulpal anesthesia in vital teeth can be measured by:

- Applying a cold refrigerant.
- Using electric pulp tester.

If patient responds to stimulus, pulpal anesthesia has not been obtained and supplemental anesthesia should be administered.

N.B: In patients with painful vital teeth (irreversible puplitis), lack of response to pulp testing may not guarantee pulpal anesthesia. Therefore if a patient experiences pain during endo treatment, supplemental anesthesia is indicated regardless of the responsiveness to pulpal testing.

9- Failure to achieve anesthesia in patients with pain

A number of explanations have been proposed.

Conventional anesthetic techniques do not always provide profound pulpal anesthesia and patients with preexisting hyperalgesia may be unable to tolerate any noxious input.

a) Inflamed tissue has lower pH, which reduces the amount of the base form of anesthetic that penetrates the nerve membrane. Thus less of the ionized form is available in the nerve to achieve anesthesia.

b) Nerves arising from inflamed tissue have altered resting potentials and decreased excitability thresholds.

c) Patients in pain often are apprehensive, which lowers the pain threshold.

10- Mandibular anesthesia:

A- Inferior alveolar nerve block (IAN):

The incidence of successful mandibular anesthesia after IAN tends to be more frequent in molars and premolars and least frequent in anterior teeth.

Onset:

Pulp anesthesia occurs within 10 to 15 min. in most cases.

Duration:

Lasts for 2 ½ hrs approximately (at least 60 min.). This can be evaluated using the electric pulp tester.

B- Incisive nerve block at mental foramen:

Successful for anesthetizing the premolars only

N.B: The combination of incisive nerve block and IAN increases the success of anesthetization of mandibular first molar but an intraosseuos or PDL injection is a better choice of supplemental anesthesia if IAN fails.

C- Infiltration injection:

A combination of labial and lingual infiltration is effective for lower anterior teeth.

11- Maxillary anesthesia:

A- Infiltration:

The most common injection for the maxillary teeth is infiltration.

Onset:

Pulpal anesthesia occurs within 5 to 7 min, but slower onset after 7 min occur in first molars.

Duration:

In anterior teeth, pulpal anesthesia declines after 20 - 30 min.

In molar teeth after 30 – 45 min.

Clinical implication:

If obturation is to be done in the same visit in case of molar teeth (duration one hr.) additional local anesthesia should be administrated.

B- Alternative maxillary injection techniques:

- Posterior superior alveolar nerve block.
- Infra orbital nerve block.
- Second division block.
- Palatal-anterior superior alveolar.
- Anterior middle superior alveolar.

12- Supplemental anesthesia:

If the standard injection is not effective

a) **Intraosseous (IO)**

b) **Periodontal ligament (PDL)**

c) **Intra pulpal (IP)**

a) **Intraosseous (IO)**

Intraosseous anesthesia can be done with intraosseous delivery system X-tip (Dentsply/ Maillefer). Fig. (1 a-d)

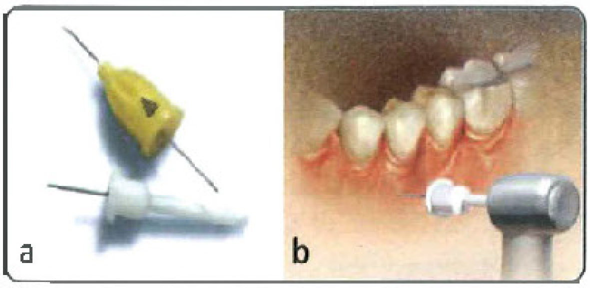


Fig. (1 – a,b): a, The X-tip system comes in two parts: the drill and the guide sleeve and special injection needle. To use the system, first anesthetize the area to be fully anesthetized with a few drops of anesthetic in the mucobuccal fold. Select a site 2 to 4 mm apical to the bony crest and between the roots. b, Place the Xtip drill and guide sleeve in a slow-speed (15,000–20,000) handpiece, and drill at maximum speed at 90° to the bone. In 2 to 4 seconds the drill will perforate the cortical bone to the cancellous bone

Fig. (1 – c,d): c, Hold the guide sleeve in place and withdraw the drill. d, Insert the special short needle into the tiny hole in the guide sleeve and slowly inject few drops of anesthetic. In the event additional anesthesia may be needed, the guide sleeve may be left in place until the end of the appointment

Periodontal ligament (POL):

In the mandible when block anesthesia is not complete.

The needle is placed alongside the root of the tooth. The bevel of the needle, not the sharp tip, faces the root.

The needle is then advanced down the PDL space, 0.02 mL of solution is slowly deposited.

Each root must be separately anesthetized.

Onset : immediate;

Duration: although limited, but enough to enter the pulp and complete the pulpectomy. Fig. (2).

Fig. 2. Incorrect insertion of the sharp needle tip toward the root (left). Correct insertion of the bevel facing the root (right).

To overcome the high pressure necessary for the technique using a standard syringe, we can use a specific PDL syringe.

PDL injections should not be used on primary teeth or teeth with periodontal infection.

2- Intrapulpal injection:

Advantages:

1. Profound anesthesia is given under back pressure to allow diffusion of anesthetic agent throughout the pulp.
2. Immediate onset and no special syringes or needles are required.

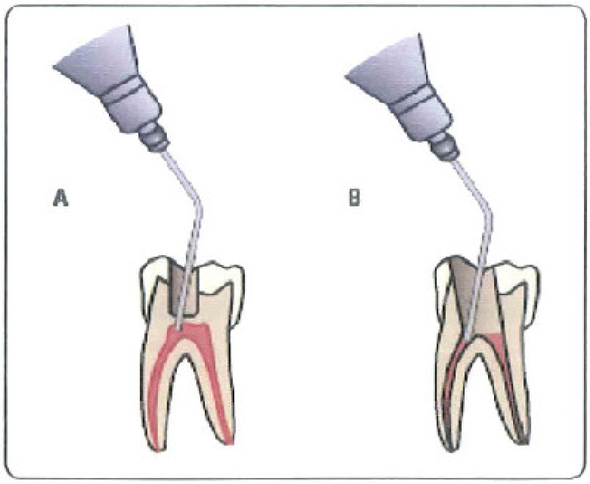


Fig. 3. Intrapulpal anesthsia

Disadvantages:

1. Pain due to injection directly into vital and very sensitive pulp.
2. Duration 15–20 min, bulk of pulpal tissues should be removed quickly to prevent recurrence of pain during instrumentation
3. Pulp must be exposed to permit direct injection, often problems with anesthetic occur before pulpal exposure.

Recent advances in delivering local anesthesia:

Although L.A injections are used to alleviate pain and reduce anxiety during treatment, yet they themselves are a source of pain and anxiety for many patients. Thus, topical anesthesia in the form of gels and sprays has been used to reduce the pain during needle stick injection. Yet some patients still experience moderate to severe discomfort after their use due to their short retention time and salivary washout. Therefore, delivering intraoral L.A through different delivery systems in the form of (discs, tablets, patches, films, hydrogels, sprays or microspheres) has attracted significant attention from academic and industrial researchers. This is because the mucosa is highly vascularized and drug diffusing across the oral mucosal membranes has direct access to the systemic circulation via capillaries and venous drainage.

Advantages:

1. Site-specific targeting allowing dosage reduction.
2. Diminishing salivary washout
3. Easy drug withdrawal (stop the action of L.A after the end of treatment section)
4. Fast onset of action.
5. High patient compliance as the pain factor associated with parenteral route can be totally eliminated.

Local Anesthetic Reversal:

Phentolamine mesylate (0.4 mg in a 1.7 ml cartridge, OraVerse) is an agent that reverses the influence of vasopressors on submucosal vessels. This agent when injected into the same site where the anesthetic was administrated, vessels dilate, leading to the enhanced absorption of L.A, thus shortening its duration of action.

Advantages:

1. Endodontic patients may benefit from the use of this agent if they have speaking engagements, meetings, or perform musical or theatrical events.
2. Children with special needs will avoid their self- injury.
3. Elderly patients will be allowed to have their nutritional intake.

Disadvantages:

1. Expensive.
2. Can only be used if post-operative pain is not anticipated, as sustained anesthesia is beneficial for management of post-operative pain.

II- Isolation in endodontics:

The use of rubber dam in root canal treatment is mandatory (Cochran et al, and Cohen and Schwartz)

1- **Advantages of tooth isolation using rubber dam:**

For the operator:

a) Provides a clean and dry field and prevents salivary leakage which is contaminated with bacteria.
b) Retracts and protects soft tissues.
c) Improves visibility and prevents fogging of the mirror upon magnification.
d) Reduces risk of cross-contamination.

e) Efficiency is increased, since it minimizes the patients conversation during treatment and the need for frequent rinsing .

f) It improves the properties of dental materials and accuracy of Electronic Apex Locators.

For the patient:

a) Enhances patient comfort by eliminating unpleasant tastes and dangerous risk.

b) Prevents aspiration or swallowing of instruments or irrigants.

2- Components of rubber dam:

A- Clamps
B- Forceps
C- Frame
D- Punch
E- Rubber dam sheet
F- Accessories

A- Clamps:

The fit of the rubber dam essentially depends on the choice of the appropriate clamp and its correct positioning. Fig. (4a-c)

i. Function of clamps:

- They anchor rubber dam to tooth.
- Help in retracting gingiva.

ii. The clamps are classified (according to material, jaw design,presence of wings)

According to material:

o **Metallic** ------- Stainless Steel (Radiopaque but stronger)

o **Non metallic** ------- Plastic which are:

- Radiolucent in x ray which is an advantage in difficult cases where the pulp chamber and canals cannot be located in these cases if metal clamps are used rubber dam should be removed, using plastic clamps the rubber dam can remain in place.

- Less likely to damage tooth structure or existing restoration.

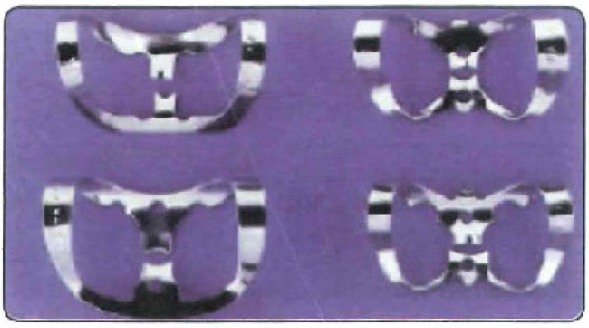


Fig. 4 a. Anterior clamps

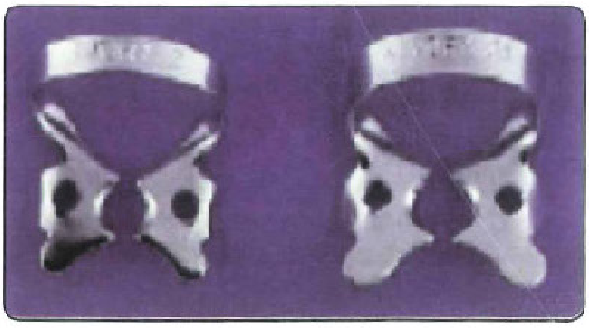


Fig. 4. b. Premolar clamps

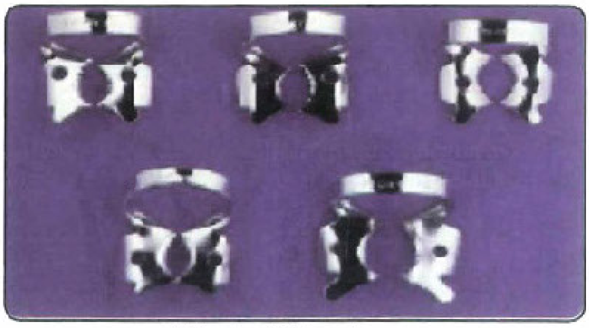


Fig. 4. c. Molar clamps

According to Jaw design:

◊ **Bland clamp :**

o Are identified by the jaws, which are flat and point directly toward each other.

o The jaws grasp the tooth at or above the gingival margin.

o They can be used in fully erupted tooth where cervical constriction prevents clamp from slipping off the tooth .

◊ **Retentive clasp**

o The jaws are usually narrow, curved which displace the gingiva and contact the tooth below the maximum diameter of the crown.

According to presence of wing:

- ◊ **Winged -------- permit the application of the rubber dam as a single unit during single tooth isolation.**
- ◊ **Wingless------- are less bulky and may be preferred in the posterior sectors in patients with particularly thick cheeks.**

Universal clamps design:

The butterfly Ivory No: 9 most anteriors and premolars.

Ivory No 56 ----- most molars.

B- Forceps:

Used to carry the clamp to tooth and it is essential that these don't have deep groove at their tips or they become very difficult to remove once clamp in place Fig. (5):

Fig. 5. Clamp forceps

C- Frame:

- * Maintains tension in the dam so that the lips and cheeks may be retracted as well.
- * Metal ------- as Young's frame.
- * Non Metal (plastic) as Nygaard-Ostby or Starlite frame (radiolucent; but bulkier).
- * New rubber dams recently introduced in the market are the Handidam (Aseptico, Woodinville, WA) and the Insti-Dam (Zirc Company, Buffalo, MN), Fig. (6: a,b). These rubber dam systems are with built in foldable radiolucent plastic frame for quick and convenient rubber dam isolation .

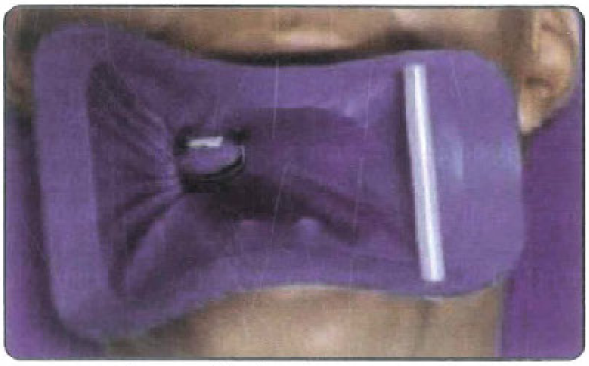


Fig. 6a. Handidam

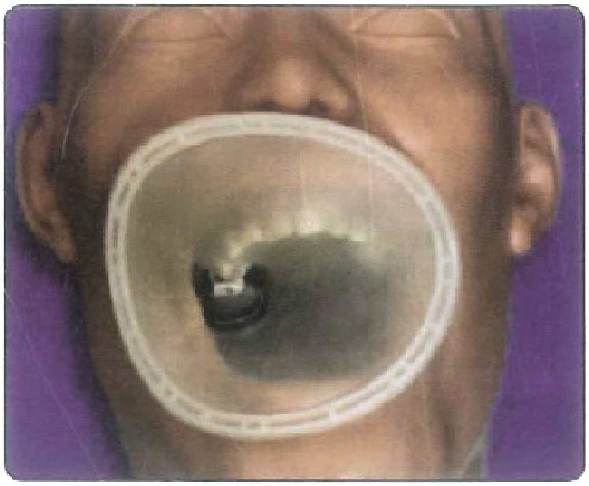


Fig. 6b. Insti-Dam

D- Rubber dam punch:

It's used to cut a hole in rubber dam sheet which is either single or multiple according to area of interest. Fig. (7):

E- Rubber dam sheet:

Classified according to:

❒ *Material:*

- Latex dam
- Latex free dam (flexidam)

Fig. 7. Rubber dam punch

❐ *Consistency:*

- Heavy
- Light
- Medium

Medium is preferred:

1. Provides a fluid tight seal.
2. Do not tear easily.
3. Superior protection of underlying soft tissues from injury.

❐ *Color :*

- Light
- Dark

N.B.: The quality of the dam sheets deteriorates with time; in particular, they lose elasticity. One should therefore stock them in moderate quantities, keep them refrigerated, and observe the expiration date on the back of the box.

To test them, just after punching a hole in the dam, it is stretched in different directions to confirm that it does not tear.

F- **Accessories**

1- Tucking instrument

- A plastic instrument used to shed the rubber dam off the wings of clamp to provide a moisture proof seal.

2- Dressing:

- Microbiological leakage between the tooth and rubber dam may occur due to prolonged endodontic procedure or during radiography due to stretching of dam.
- Application of dressing material ensure complete seal including tears in the dam and prevent leakage eg. Oraseal.

3- Lubricant

Before positioning the dam, it is advisable to lubricate the inner surfaces well with Vaseline or, more simply, soap, so that the sheet will slide better over the contours of the teeth, more easily overcome the contact areas, and close tightly around the cervix of the tooth

4- Rubber dam napkins

a. These prevent direct contact between the rubber sheet and the patient's cheek.

b. Their use is not mandatory; however, they are particularly indicated in cases of allergy to the rubber of the dam.

5- Dental floss

Preventing the ingestion or aspiration of the clamp.

6- Elastic wires

Elastic wires of different thickness to keep the rubber dam in place. Fig. (8).

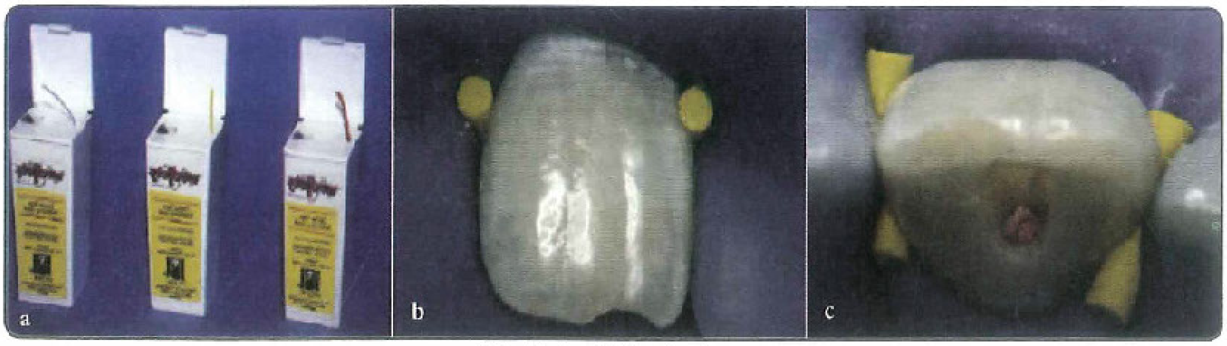


Fig. 8. (a-c) Elastic wires

3- **Techniques of rubber dam application:**

a. Application of sheet followed by clamp and frame.

b. Application of clamp followed by sheet and frame.

c. Attaching the clamp to sheet and frame outside patients mouth and then placed as one unit to the required tooth.

4- **Isolation in difficult cases:**

A- ***Extensive loss of coronal tooth structure:***

i. Use retentive clasps and deep reaching clamps.

ii. Punch a bigger hole so that the sheet can be stretched to include more teeth.

iii. Orthodontic bands cemented to support tooth with large undermined wall.

iv. Gingivectomy may also be used.

v. Build up:

When to build up?

1. If the tooth is deemed restorable but the margin of sound tooth structure is subgingival
2. If insufficient tooth structure prevents the placement of a clamp
3. Cracks on the remaining tooth structure, so place, **build up immediately**

Build up can be accomplished by:

1- A preformed copper band, a temporary crown, or an orthodontic band may be cemented over the remaining natural crown.

2- If so little tooth structure remains that even band or crown placement is not possible. In these cases it becomes necessary to replace the missing tooth structure to facilitate placement of the rubber dam clamp and prevent leakage into the pulp cavity during the course of treatment.

3- *Canal Projection:*

Canal projection is a technique that facilitates pre endodontic buildup of broken *down coronal* and radicular structure while preserving individualized access to the canal.

Material used for canal projection:

Although any of a number of syringeable materials (glass ionomer cements, temporary cements, permanent cements, etc.) and even "packable" composites may be used to project the canals, ***bonded injectable autopolymerizing composites*** have proven to be the most versatile and reliable buildup material for this technique

Technique:

1. In curved canals, straight-line access is created to the first significant curvature by removing dentin "triangles" with small, slow-speed round burs, working into the bulk of each root (i.e., working away from the furcal aspect of the root). Fig (9A)
2. If there is no significant curvature in a particular canal, then the orifice should be dimpled to the depth of a #2 slow-speed round bur.
3. An appropriate matrix barrier is applied, and all bondable surfaces are etched and primed.
4. Files are selected that will fit well into the body of each canal, and projectors (CJM Engineering, Santa Barbara, CA), tapered plastic sleeves available in various dimensions, are placed onto the files. Fig (9B)
5. The files are then inserted into the canals, and the projectors are slid apically until they are drawn into the seat of the previously prepared straight-line access or dimples. Fig (9C)
6. Inject an appropriate auto-polymerizing material such as composite or glass ionomer into the chamber, injecting it from the bottom up to avoid trapping air bubbles. Fig (9D)

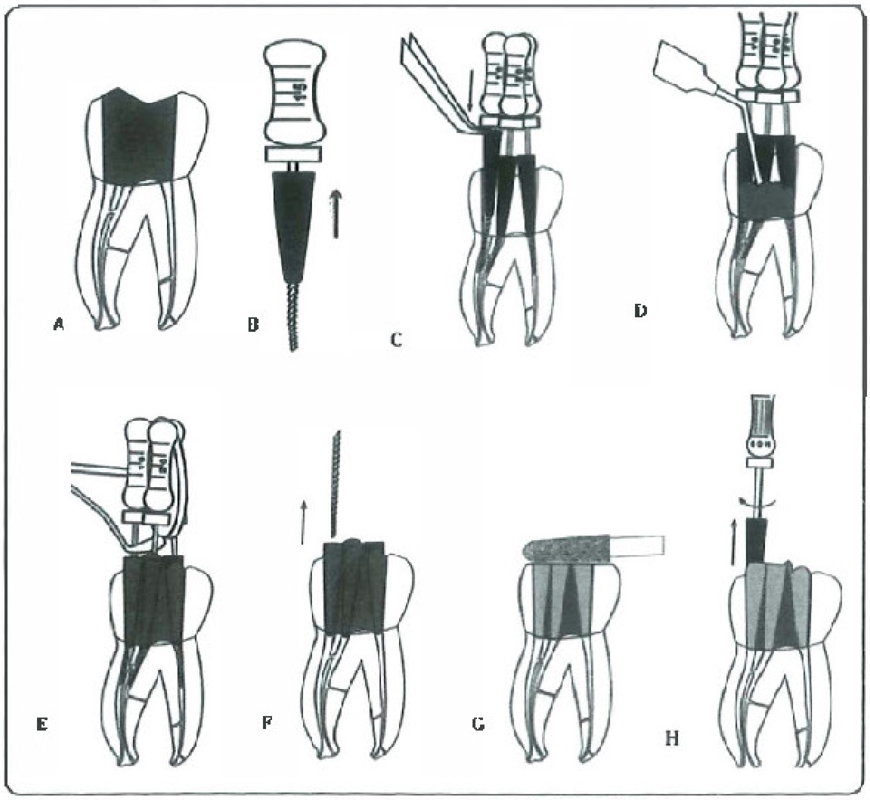


Fig. 9. Steps of the Canal projection technique

7. Make certain the file handles are in desired alignment. Fig (9E)
8. At an early stage of polymerization, work the files in several short vertical strokes, then carefully remove them Fig (9F)
9. Flatten the surface of the polymerized projection matrix and the coronal portion of the imbedded Projectors using a high-speed, bull-nosed diamond. Fig (9G)
10. Remove Projectors by inserting a No. 60 or larger Hedstrom file, rotating it to engage the flutes in the lumen of the Projector. Fig (9H)

Advantages of canal projection technique:

1. Isolation
2. Seal of chamber floor
3. Elongation of canals
4. Overlay of perforation repair
5. Prevention of perforation
6. Reduced potential for crack initiation or propagation
7. Prevention of ingrowth of tissue
8. Individualization of canals in multicanal teeth
9. Elimination of "blind exploration" on the chamber floor and improvement of mechanics related to handpiece-driven files

B- <u>Crowns with poor retentive shapes:</u>

i. Placing clamp on another tooth.
ii. By building retentive shapes on the crown using composite bonded to etched tooth surface.
iii. Using deep reaching clamps.
iv. Ligation: with dental floss or using interproximal wedgets.

C- Teeth with porcelain crowns:

- In some cases application of clamp may cause crown fracture.

  How to avoid?

1. Clamp should be paced on another tooth.
2. Clamp should engage below crown margin.
3. Placing a layer of rubber dam sheet between clamp and porcelain will act as a cushion.

5- Contraindications of rubber dam:

a. Asthmatic patients.

b. Mouth breathers.

CHAPTER REVIEW QUESTIONS

1- What are the possible adverse effects of a local anesthetic agent?

2- Describe the supplemental anesthetic techniques used in endodontics

3- Describe the recent advances in delivering local anesthesia and the local anesthestic reversal

4- Describe the different components of rubber dam and their functions.

5- Discuss the canal projection technique for build up and its advantages

REFERENCES

- Ingle J. PDQ Endodontics. Access to the Root Canal System.p 58-70. 2005. BC Decker Inc
- Hargreaves and Cohen. Pathways of the Pulp. 10thed 2011. Mosby. Elsevier.
- Garg N, Garg A. Textbook of Endodontics: case selection and treatment planning.p103-110. 1st ed 2007.JAYPEE.
- Taware CP, Mazumday S, Penharkan M, Adani M, Devarjan PV. A bioadhesive delivery system as an alternative to in ltration anesthesia. Oral Surg Oral Med Oral Pathol Oral Radiol Endodod 84:609, 1997.
- Carr MP, Horton JE Evaluation of a transoral delivery system for topical anesthesia. J Am Dent Assoc 132:1714, 2009
- Jug M, Maestrelli F, Bragagni M, Mure P. Preparation and solid-state characterization of bupivacaine hydrochloride cyclodextrin complexes aimed for buccal delivery. J Pharmaceutical and Biomedical analysis 52:9, 2010.
- Patel VF, Liu F, Brown MB. Advances in oral transmucosal drug delivery. Review 153:106, 2011.
- Movassghian S, Afzalifar R, Alaeddini M. Clinical anesthetic Effectivness of intraoral mucoadhesive tablets of Amitriptyline in healthy volunteers. J Oral Maxillofac Surg 71:23, 2013.
- Hers E, Moore P, Papas A et al. Reversal of soft tissue local anesthesia with phentolamine mesylate in adolescents and adults. J Am Dent Assosc 139:1080,2008.
- Torabinejad M, Walton RE, Fouad AF Endodontics: Principles and Practice 5thed . Saunders.2015
- http://www.dentistrytoday.com/endodontics/1036.html

17 Emergency Treatment in Endodontics

Maged Negm

Intended Learning objectives

After reading this chapter, the student should be able to

1. Understand types of emergencies in dentistry.
2. Know the classification of endodontic emergencies.
3. Describe steps of proper diagnosis.
4. Know pretreatment emergency cases.
5. Recognize the signs and symptoms, diagnosis and emergency treatment of acute pulpitis.
6. Recognize the signs and symptoms, diagnosis and emergency treatment of acute pulpitis with apical periodontitis.
7. Recognize the signs and symptoms, diagnosis and management of pulp necrosis.
8. Recognize the signs and symptoms, diagnosis and full treatment of acute periapical abscess.
9. Identify the causes and prevention of interappointment pain.
10. Recognize the signs and symptoms, diagnosis and emergency treatment of secondary acute apical periodontitis.
11. Recognize the signs and symptoms, diagnosis and emergency treatment of incomplete removal of pulp tissue.
12. Recognize the signs and symptoms, diagnosis and emergency treatment of phoenix abscess.
13. Determine the post appointment emergencies and understand the management and treatment of these cases.

Postgraduate students should be able to

1. Understand the definition of flare-up.
2. Analyze endodontic emergencies and their etiology.
3. Criticize the different approaches for management of acute periapical abscess.
4. Assess points of differences between acute periapical abscess and Phoenix abscess.
5. Criticize open vs. closed access cavity used for drainage.
6. Correlate inter-appointment emergencies with inter-appointment emergency cases.

Chapter Outline

CATEGORIES

Pretreatment emergencies.

Inter-appointment pain.

Inter appointment emergencies.

Post-appointment emergencies.

THE CHALLENGE

Differentiation of emergency and development of plan of treatment.

Classification of emergencies in a practical way.

Signs and symptoms related to clinical cases.

Diagnosis in an applied way.

Management and treatment as an emergency.

Emergency in dentistry may be classified into: pain and swelling

Emergency Visit means treatment done in the first visit

85 to 90% of emergency cases in the dental field are due to

PULPAL and/OR PERIAPICAL REASONS

An endodontic flare-up is defined as an acute exacerbation of a periradicular pathosis after the initiation or continuation of non surgical root canal treatment. Incidence may be from 2% to 20% of cases.

Classification:

Pretreatment Emergencies

Inter-appointment emergencies

Post-appointment emergencies

Post treatment emergency: a term used after SINGLE VISIT treatment.

For proper diagnosis you must:

Obtain brief medical and dental histories.

Ask objective questions about pain such as:

location severity duration character stimuli – onset.

Perform pulp testing.

Perform palpation and percussion testing.

Perform a good radiograph.

PRE-TREATMENT EMERGENCIES

Acute pulpitis

Acute pulpitis with apical periodontitis

Pulp necrosis

Acute periapical abscess

PRE-TREATMENT EMERGENCIES

I. Acute Pulpitis:-

Severe, excruciating, throbbing pain:
Increase at night.
Increase when patient is lying down.
Relieved by cold.
Spontaneous or caused by an irritant.

Referred / diffuse (due to absence of pressure receptors).

Acute Pulpitis:-

Early stage pain … increased by heat and cold.

Severe, excruciating, throbbing pain, increases at night or when patient is lying down.

Visual examination and history:

Caries – deep filling – trauma – history of irritation.

Pain is diffuse and caused by an irritant or spontaneous.

Palpation and percussion …. –ve.

Radiographs …. – ve or slight widening in the lamina dura.

Vitality tests:

Thermal.

Early stage: Heat and cold elicit sharp pain.

Intermediate stage: Heat increases pain while cold relieves pain (hot tooth).

Late stage: Heat and cold cause persistent pain.

Pulp tester: severe pain at low current (low reading).

Emergency treatment: Pulpectomy/ pulpotomy

Pulpectomy

Premedication with anti-inflammatory agent.

Deep L.A.

Access cavity and pulp exposure with ultra high speed under efficient cooling.

Intrapulpal anaesthesia.

Pulp extirpation.

Irrigation.

Dryness with paper points.

Dry cotton and temporary dressing.

Pulpotomy

Removal of the pulp from the pulp chamber only by means of sharp spoon excavator or large round bur at low speed .

Dryness of blood.

Insertion of a cotton pellet saturated with formocresol into the pulp chamber for 1 minute.

Removal of the cotton pellet and insertion of another pellet lightly dampened with formocresol into the pulp chamber.

Dressing with temporary filling over the cotton pellet.

Patient is recalled after 2 – 3 days for RCT.

Formocresol causes fixation of pulp tissue inside the canals to stop the inflammatory process and hence pain.

II. Acute Pulpitis With Apical Periodontitis:-

Inflammation of the pulp which has extended to involve the periapical tissue.

Signs and symptoms:

All signs, symptoms, radiographic and pulp testing are the same of that of acute pulpitis, besides pain is:

Localized .

Tooth elongation.

Tenderness to percussion.

Emergency treatment:

Pulpectomy

III. Pulp necrosis:

Necrosis Is Not An Emergency…

Yet It May Create An Emergency!!

Pulp necrosis

It may cause an emergency when:

1. Necrotic remnants extend to the periapical tissue, or
2. Pushed by the operator to pass the apical foramen into the periapical area.

Signs and Symptoms:

No complaint – no response to vitality tests and percussion.

Radiographically ….. Slight widening in the lamina dura.

Emergency treatment:

Debridement of necrotic remnants are performed over two visits to avoid pushing of remnants and bacteria periapically .

In the first visit remove remnants from coronal $^2/_3$ of the canal. In the second visit remove remnants from the apical $^1/_3$. However, total removal of remnants may be done in the first visit followed by injection of intracanal calcium hydroxide.

A cotton with medicament and temporary filling are used between visits.

IV. Acute Periapical Abscess:-

Signs andSymtoms:

Vitality: …. Some vital response to EPT. or non vital.

Swelling: either …. absent with severe pain (early stage).

Localized or diffuse with less pain (late stage).

Severe, throbbing pain.

Tooth feels elongated with tenderness to biting.

Tenderness to percussion.

Radiography. Ranges from widening of the lamina dura to periapical radiolucency.

Patient is …. febrile or afebrile.

emergency treatment

Anaesthesia …nerve block or ring block.

Infiltration anaesthesia into the abscess is contraindicated because of :

- *Pain.*
- *Dissemination of microorganisms.*
- *Dilution of anaesthetic solution into the pus.*

Drainage of pus:

First choice ….. Through the canal.

Second choice … Incision and drainage (I & D).

Drainage through the canal:

Access cavity.

Deroofing.

Drainage through the cavity which could be helped by aspiration using suction device.

If pus does not drain through the access cavity, mechanical preparation is done pushing the instruments out of the apical foramen for a distance of 2-3 mm to remove the apical constriction.

Apical constriction is widened up to size 30 file.

Reaching this size pus either:

Drains or does not drain.

Pattern of drainage:

Yellowish, white, or greenish white in colour followed by:

Pus mixed with blood, pus bloody tinged, blood,

then a clear serum exudate

Irrigation First visit: warm saline or distilled water

NaOCl has tendency to clump the pus

Second visit:

NaOCl (from 0.5% to 5.25%)

or

alternate use of H_2O_2 and NaOCl

Begin with H_2O_2 (oxidizing agent),

followed by NaOCl (reducing agent).

Repeat the process and make sure that the final solution is NaOCl.

These two solutions make foaming when used together and will aid in bubbling out of debris and pus

H_2O_2 ...... release nascent O_2.

NaOCl .....reduces excess O_2 and hence prevents its build up.

Build up O_2 leads to emphysema causing pain in the periapical tissues.

After irrigation dry with paper points followed by dry cotton and temporary filling.

Reappoint at 1 – 3 days.

Prescribe antibiotics.

Sealing with temporary filling is very important.

If access cavity was not closed it may allow:

Packing of food debris into the canals.

New types of microorganisms pushed into the canals causing superimposed infection.

When access cavity should be kept unclosed???

Access cavity is kept open when: drainage of pus does not stop, flare up persists or takes place in the periapical tissues.

Open access cavity.

Prescribe antibiotics.

Second visit:

Debridement with barbed broach

Enlarge the canals to approximately one size smaller than the final size file.

Keep access open.

Next visit:

Apply rubber dam.

Debridement with barbed broach ... no filing.

Heavy irrigation and then dry with paper points.

Close with dry cotton pellet and temporary filling.

Filing at this visit may push debris or bacteria periapically causing flare up.

Last visit:

Apply rubber dam.

Remove temporary filling.

Instrumentation is done to the final size file.

Master cone and obturation.

Rule of open access

If you file do not close ... if you close do not file

Time between each visit and the next ranges between 1 and 7 days.

Inability to drain through the canal:

This could happen when:

Pus is extremely viscous.

Pus penetrated alveolar bone and accumulated submucosally.

Presence of post and core.

Presence of broken instrument.

Calcification.

Inability to damage an existing restoration.

Incision and Drainage (I and D)

A stab incision is made below the most dependent point of the swelling Fig. (1).

The compact bone is probed with an explorer to locate a perforation.

Artificial fistulation or trephination may then be done.

Artificial fistulation (Artifistulation):

The point of perforation in cortical bone plate is widened by either a sharp spoon excavator, periodontal curette or large size endodontic file.

Pus will then drain out.

Trephination:

If artifistulation fails to give sufficient drainage, trephination is done.

A tapering fissure bur or round bur is used to create multiple holes in the cortical bone in a form of a circle of 1cm in diameter.

The fissure bur is then used to connect these holes together under sufficient water cooling.

The root apex and surrounding lesion will be uncovered and drainage obtained.

Insertion of a drain:

To allow further drainage a strip of rubber dam material of 2x2 cm is cut to resemble letter H or T and then disinfected Fig. (2A).

One half of the drain is placed inside the periapical area and the other half protruding outside the flap Fig. (2B).

The junction between the 2 halves of the drain is sutured to the unretracted edge of the flap to keep it open for drainage.

Antibiotics are prescribed and another appointment is given after 3-5 days.

In the subsequent appointment the drain is removed and suturing of the flap is done.

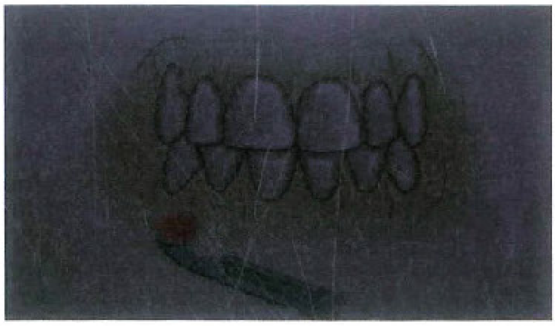


Fig. 1. A stab incision below the most dependent area.

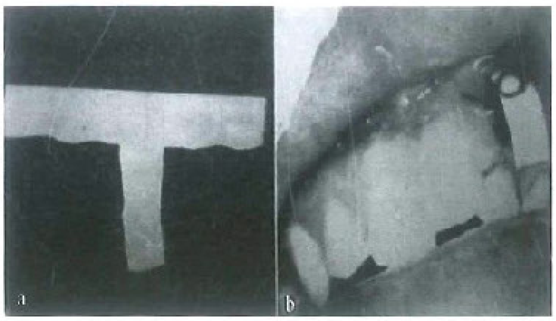


Fig. 2. (a) A piece of rubber dam "T shaped" (b) drain in place

INTER-APPOINTMENT EMERGENCIES

Procedures which cause or increase pain are:

1. Mis-diagnosis:

   Causes: incorrect identification of the offending tooth.

   Pain originating from another source.

   Prevention: proper careful diagnosis.

2. Missed canal:

   Causes: lack of information of macroscopic anatomy, lack of clinical experience.

   Prevention: studying of teeth anatomy,use of the shift technique in periapical radiographs.

3. Incomplete removal of pulp tissue:

   Causes: inserting instruments half way into the root canal producing further irritation of the remaining inflamed tissue in the canal.

   Severe pain especially with hot and cold would follow.

   Prevention: complete removal of pulp tissue (pulpectomy).

4. Overinstrumentation:

   Causes: overinstrumentation beyond the apical foramen.

   Prevention: correct determination of the working length and hence limiting instrumentation to the tooth length.

5. Method of irrigation:

   Causes: forcing irrigating solutions into the canals under pressure

   Prevention: avoid pressure and the needle should be kept in up and down motion during irrigation.

   You may use laterally perforated needles (Fig 3).

6. Open versus closed access:

   Open access may cause:

   Packing of food and saliva.

   Superimposed infection by new microorganisms takes place.

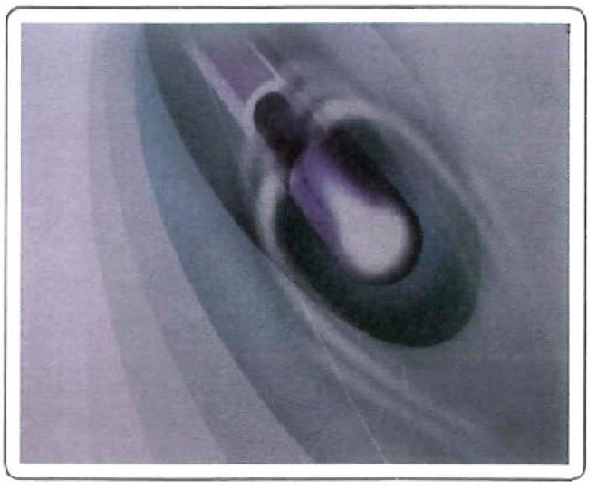


Fig. 3 a. Laterally perforated needle.

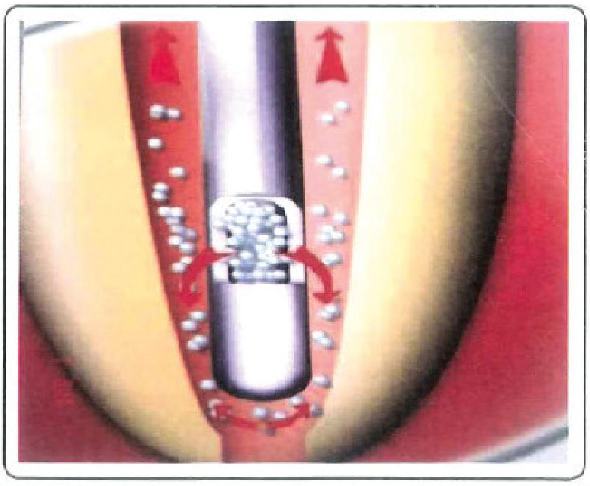


Fig 3 b. Solution coming out from the needle.

   Prevention: keep the access sealed with temporary dressing.

   However, tooth may be kept open in case of:

   - Presence of diffuse swelling or cellulitis.
   - Excessive discharge.

7. Intracanal medicaments:

   Causes: overmedication permeates medicaments into periapex producing inflammation and pain.

   Prevention: their use is limited to certain cases and should be kept into the pulp chamber only.

   $Ca(OH)2$ paste is currently recommended as a medicament in case of:

   Persisting exudation (weeping canals).

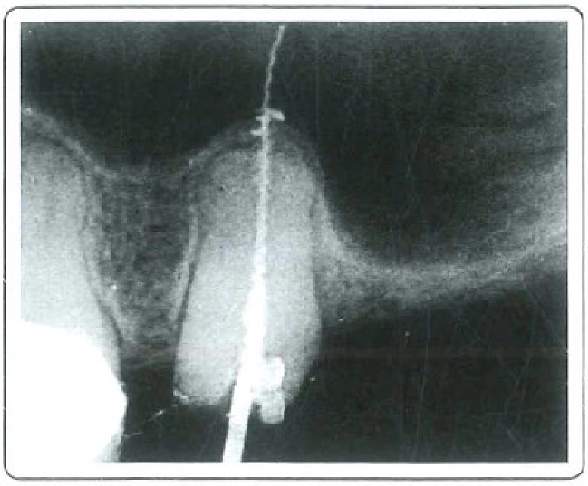


Fig. 4. Overinstrumentation forcing debris periapically.

Presence of necrotic pulp partially or completely removed.

Flare up cases.

8. High occlusion:

Causes: High points in the temporary filling between visits.

Prevention: Bringing the tooth and filling slightly underocclusion between visits.

Inter-Appointment Emergencey Cases

1. **Secondary acute apical periodontitis.**
2. **Incomplete removal of pulp tissue.**
3. **Phoenix abscess.**

1- Secondary Acute Apical Periodontitis

Causes: - Overinstrumentation Fig. (4).

- Overmedication.

- Forcing debris into the periapical tissue Fig. (4).

Symptoms:

- Pain to percussion.
- Throbbing, gnawing and pounding pain.
- Tooth elongation.

Diagnosis:

It is confirmed by inserting a thin sterile paper point into the canal and pushing it for a distance of 1 or 2mm longer than the working length

First: paper point will extend easily past the apical foramen.

Second: on withdrawal the tip will disclose a reddish or brownish color indicating inflamed periapical tissue and absence of apical stop Fig. (5).

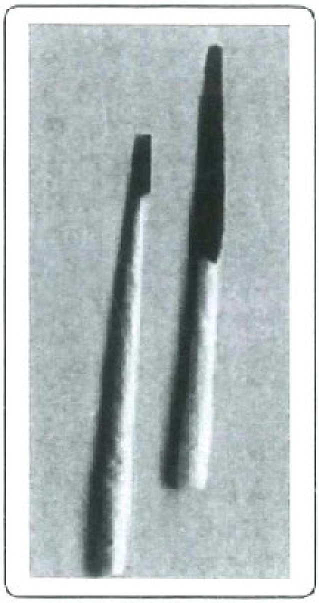


Fig. 5. Paper points with blood traces

Treatment:

- Inserting a polyantibiotic-corticosteroid paste into the periapical tissue by means of a thin paper point.
- Injecting $Ca(OH)_2$ paste into the root canal and sealing it with a temporary filling for few days.

2- Incomplete Removal Of Pulp Tissue

Symptoms:

Sensitivity to hot and cold.

Pain to percussion.

Diagnosis:

A sterile paper point is inserted into the canal definitely short of the working length.

On withdrawal the tip of the point will display a brownish discoloration indicative of presence of inflamed seeping tissues.

Treatment:

Determine the correct tooth length and extirpate the remnants of the pulp tissues (Fig 6).

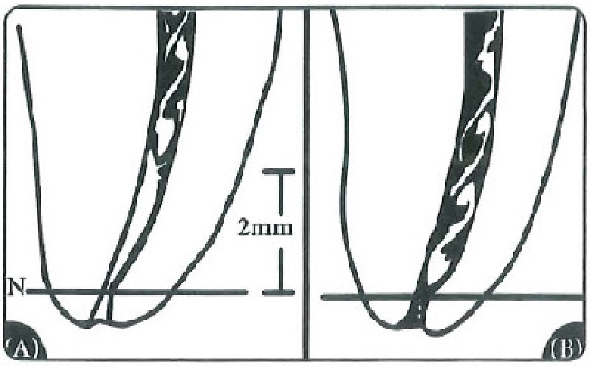


Fig. 6 Incomplete and complete removal of pulp tissue

3- Recrudescence of a chronic periapical lesion (Recrudescent or Phoenix abscess):

Acute exacerbation of a chronic lesion.

Chronic lesions may become acute during endodontic treatment.

This condition is referred to as:

Recrudescence means.... Breakingout anew

Phoenix means..... Rebirth

Recrudescence of a chronic periapical lesion:

Causes:

Pushing new strains of microorganisms into the periapex.

Pushing or forcing necrotic debris.

Overinstrumentation.

Symptoms:

The same symptoms of acute periapical abscess together with:

1. Definite tooth mobility.
2. Complete loss of response to vitality tests.
3. Well defined periapical radiolucency.

Treatment:

The same treatment of acute periapical abscess

III.POST-APPOINTMENTEMERGENCIES

About one third of endodontic patients complain of pain after obturation.

Causes:

Irritation by obturation materials.

Overfilling.

Extrusion of sealer periapically.

Poor seal (leakage).

High occlusion.

Management:

1. Adequate, acceptable root canal filling.

Pain only .... reassurance and analgesics.

Pain and swelling ... I and D and antibiotics.

2. Inadequate, unacceptable root canal filling.

   a. Correctable

      Retreatment (root canal therapy)

   b. Incorrectable

      Surgical intervention (apical surgery)

CHAPTER REVIEW QUESTIONS

1. Discuss signs, symptoms and emergency treatment of acute pulpitis with apical periodontitis.
2. Describe emergency treatment of acute apical abscess.
3. What are the causes and preventive measures of inter-appointment pain?
4. Compare signs, symptoms and emergency treatment of acute periapical abscess and recrudescent abscess.
5. Give an account of post-appointment emergencies and their management.

REFERENCES

- Hargreaves KM, Cohen S. Cohen's Pathways of the Pulp. 10th ed. Mosby El Sevier, 2011.
- Beer R, Baumann MA, Kielbassa AM. Color Textbook Atlas of Endodontics. 3rd ed Milestone publisher, 2009.
- Arens DE, Adams WR, De Castro Endodontic Surgery. 10th ed. Harper and Row Publishers,1980.
- Bence R, Weine FS Handbook of Clinical Endodontics. 2nd ed. The C.V. Mosby company. 1980.
- Walton RE, Torabinejad M. Principles and Practice of Endodontics. 2nd ed. W B. Saunders Company. 1996
- Gutmann JL, DumshaTC,Lovdahl PE. Problem Solving in Endodontics. Prevention, identification, and management. 4th ed. Mosby El Sevier, 2006.
- Weine FS Endodontic therapy. 5th ed Mosby-Year book, Inc, 1996

18 Traumatic Dental Injuries

TECHNICAL & CLINICAL ENDODONTICS

Manar Y. Fouda

Intended Learning objectives

After reading this chapter, the student should be able to

1. Classify traumatic dental injuries.
2. List pertinent information needed when examining patients with dental injuries from chief complait, history, nature of injury and symptoms.
3. Describe the diagnostic tests and procedures used in examining patients with dental injuries and interpret the findings.
4. Describe the clinical and radiographic features of traumatic dental injuries including; enamel fractures, uncomplicated crown fractures, complicated crown fractures, root fractures, crown-root fractures, tooth luxations as (concussion, subluxation, extrusive luxation, intrusive luxation), avulsions and alveolar fractures.
5. Recognize possible short and long term responses of pulp to the various types of traumatic dental injuries.
6. Describe the appropriate emergency treatment strategies as well as the long term ones for the various types of traumatic dental injuries.
7. Recognize outcomes and prognosis of traumatic dental injuries.
8. Describe management considerations for surface root resorption, inflammatory resorption and replacement resorption .

Chapter Outline

Traumatic injuries to the tooth result in damage to many dental and periradicular structures. Although the immediate consequences may appear obvious and dramatic ,yet in many circumstances, the true picture takes time to emerge. knowledge of the interrelating healing patterns of this tissue is essential to manage the multifactorial consequences of these injuries.

Causes of traumatic dental injuries:

Traffic accidents

Falling while running

Acts of violence and

Sports accidents

Incidence of traumatic injury:

1) *Age:*
   - Deciduous most common (2-5 years).
   - Permanent (7-12 years).
2) *Sex:* Boys > girls 2:1.
3) *Site:*
   - Mandibular incisor.
4) *Occlusion; Malocclusion predisposition.*

Classification of traumatic dental injuries

Based on Andreasen's modification of the World Health Organization's(WHO) classification this classification system is preferable as it has a descriptive format based on anatomic and therapeutic consideration(Fig 1,2).

- *Enamel fracture: Involves the enamel only and includes enamel chipping and incomplete fractures or enamel cracks.*
- *Crown fracture without pulp exposure: An uncomplicated fracture involving enamel and dentin with no pulp exposure.*
- *Crown fracture with pulp exposure: involving enamel and dentin with pulp exposure.*
- *Crown- root fracture: Tooth fracture that includes enamel, dentin and root cementum and may or may not include the pulp.*
- *Root fracture: Fracture of the root only involving cementum dentin and the pulp.*
- *Luxation injuries: tooth luxations include concussion, subluxation extrusive luxation, lateral luxation, and intrusive luxation.*
- *Avulsion: Complete displacement of a tooth out of its socket.*
- *Fracture of the alveolar process (mandible or maxilla):fracture or communication of the alveolar socket or of the alveolar process .*

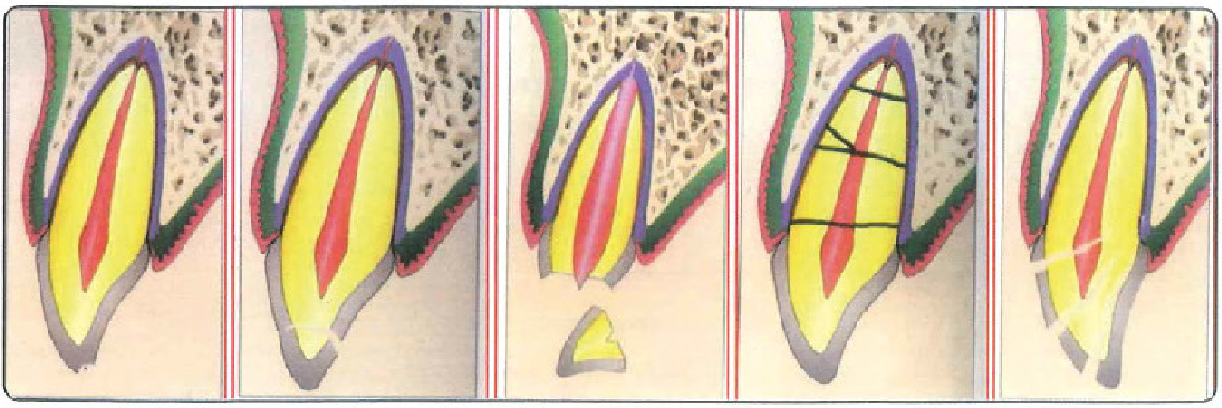


Fig. 1. Tooth fractures; enamel fracture, uncomplicated crown fracture, complicated crown fracture, root fracture, and crown root fracture.

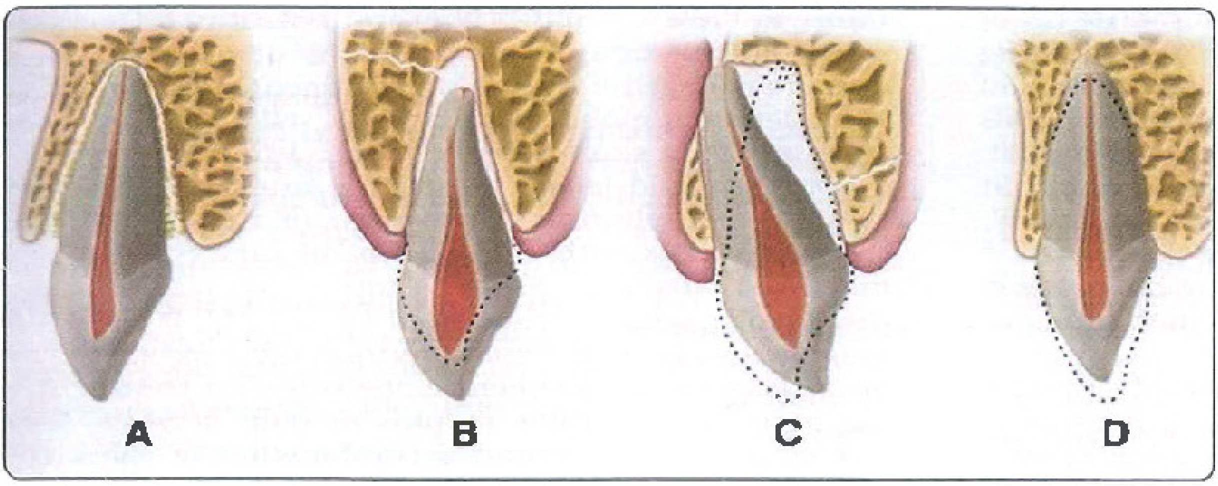


Fig. 2 Tooth luxations; subluxation, extrusive, lateral luxation and intrusive luxation.

Examination and Diagnosis

The examination process of trauma patients is similar to the regular examination of all endodontic patients including case history, clinical examination with the aid of the vitality test and radiograph.

Chief Complaint

The chief complaint may appear obvious in traumatic injuries. However, the patient should be asked about severe pain and other significant symptoms.

History of Injury

To provide information about the accident in chronologic order and determine what effect it had on the patient.

How did the injury happen? To assist in locating specific injuries and teeth involved.

When and where did the injury happen?

Have you had dental treatment before?

Have you noticed any symptoms since the injury?

Medical History:

The patient medical history is often significant especially to clear:

- Allergic reactions to medications.
- Disorders e.g. bleeding problems, diabetes & epilepsy.
- Current medications; to avoid unwanted drug interactions
- Tetanus immunization status

Clinical examination:

Extraoral examination

Head and neck neurological examination for;

- Abnormal signs and symptoms,
- Abnormal affirmative response.

Facial bones; the maxilla, mandible and TMJ are palpated externally to detect any possible fractures, or deviation from the normal bony contour.

Laceration of the soft tissues.

Intraoral examination

Soft tissue examination;

Lacerations of lips and tongue must be radiographically examined for embedded foreign objects (Fig 3).

Areas adjacent to fractured teeth should be carefully examined and palpated for areas of swelling, tenderness and bruising.

Fig. 3. Tooth fragment embedded in lip. A radiograph of the lacerated lip showed tooth fragment embedded

Hard tissue Examination (Fig 4):

Several teeth are out of alignments means fracture of mandible or maxilla.

Loose tooth means displacement from alveolar socket.

Movement of several teeth indicate alveolar fracture.

Displaced tooth is tender to percussion due to accumulation of extravasated fluid and hemorrhage in the gingival sulcus is a common finding.

Mobility of the tooth is recorded and crown mobility should be differentiated from tooth mobility.

The mandible should be examined for fractures by placing the fore fingers on the occlusal plane of the posterior teeth with the thumbs under the mandible and then rocking it gently but with firm pressure from side to side and from anterior to posterior direction, sound of the broken parts may be heard.

Sensitivity tests

Subsequent to traumatic injury, the traumatized tooth is vulnerable to *false negative* readings from an electrical or thermal stimulus. The conduction capability of the nerve endings and/or sensory receptors is sufficiently deranged to inhibit the nerve impulse of such tests.

It may take as 9 months for normal blood flow to return to coronal pulp of a traumatized fully formed tooth. So teeth that respond negatively to pulp testing can't be assumed necrotic and may give positive response later. Also teeth that respond positively at the initial test had to be followed up later.

Thermal and electrical pulp tests of all anterior teeth (canine to canine) of the maxillary and mandibular jaws should be performed at the time of the initial examination and carefully recorded to establish a baseline for comparison with subsequent repeated tests at 3 weeks; at 3, 6, and 12 months; and at yearly intervals after the trauma.

The electrical pulp test relies on electrical impulses directly stimulating the nerves of the pulp. They are useful when the dentinal tubules are closed and do not allow dentinal fluid to flow in them as in elderly patient or in traumatized teeth that are undergoing premature sclerosis. However, these tests have limited value in *young teeth*.

Recently, ***Laser Doppler Flowmetry*** (*LDF*) technology have been attempted in traumatized teeth because this would provide a more accurate reading of the vitality status of the pulp

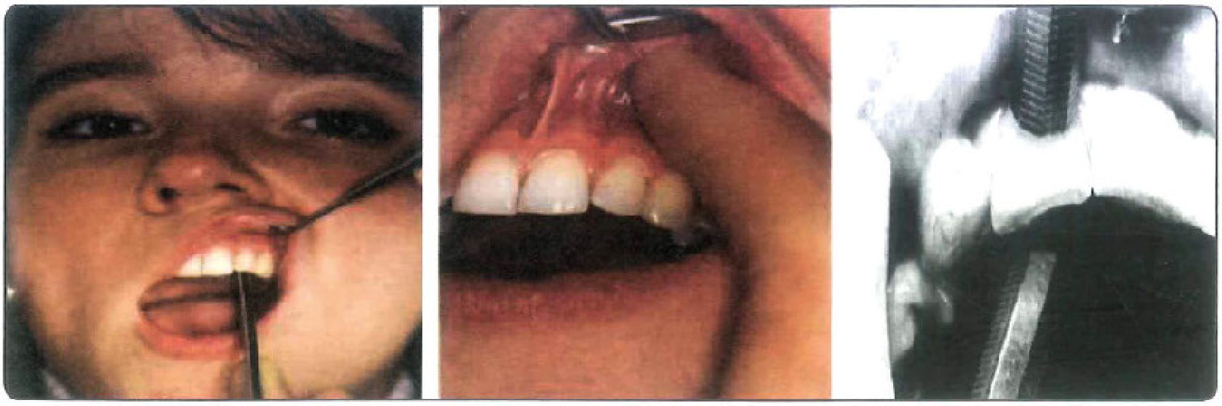


Fig. 4. Percussion, palpitation and mobility. The tooth is examined in all directions including axially & recorded

Radiographic examination

It revels root fractures, sub-gingival crown fracture, tooth displacements, bone fracture and root resorption. Also, dimension of root canal space, apical closure and proximity of the fracture line to pulp are outlined from the radiographs. Occlusal or panoramic radiographs are helpful tools for bone fracture detection.

For the management of traumatic dental injuries, the International Association of Dental Traumatology (IADT) has recommended taking at least four different radiographs for almost every injury; a direct 90-degree on the axis of the tooth, two with different vertical angulations, and one occlusal film.

Limitations of the radiograph include inability to reveal fracture line running in mesio-distal direction, diagonal fracture line in bucco-lingual direction and hairline fracture

Recently, ***Cone Beam computed tomography*** (CBCT), imaging techniques has been suggested as an adjunct tool when the true nature of the dentoalveolar root fracture and dental injuries cannot be diagnosed from a conventional examination and radiographs. CBCT provides precise, essentially immediate, and accurate 3D radio graphic images (fig 5,6).

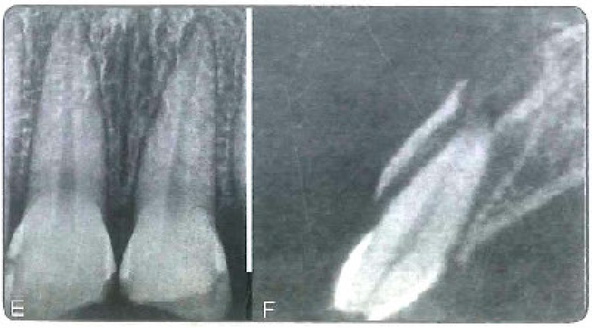


Fig. 5. Periapical radiograph of upper central incisors revealed crown fractures. CBCT Sagittal view imaging of the left incisor of the same patient revealed a lateral luxation displacement injury with extensive concomitant alveolar fracture.

Fig. 6. Periapical radiograph of upper centrals and left lateral incisors, that had recently been splinted in an emergency room. CBCT Sagittal view imaging of the lateral incisor revealed how severe the displacement was.

Management of Traumatic Injuries

Enamel fracture

Also called crown infractions. Include chips and cracks confined to the enamel and not crossing enamel dentin border. Theoretically, these fractures are "*Weak points*" through which bacteria & their by-products can travel to challenge the pulp.

Diagnosis: using transillumination to detect the cracks or the presence of sharp or rough edges.

Emergency treatment: grinding and smoothening the rough edges or restoring the lost tooth structure.

Follow up and Prognosis: The prognosis is good, however, the injury that produce the fracture may also have displaced (luxated) the tooth and damaged the blood vessels supplying the pulp

Meticulous follow up, up to 5 years, is a preventive endodontic measure.

Sequelae of this injury; pulp necrosis, internal resorption and calcific metamorphosis

Uncomplicated Crown fractures (no pulp exposure) 33%-50%) (Fig 7,8)

The outcome of exposed dentinal tubules-- irritation to the pulp or pulp necrosis depends on age of patient, surface area exposed, length of time to start treatment.

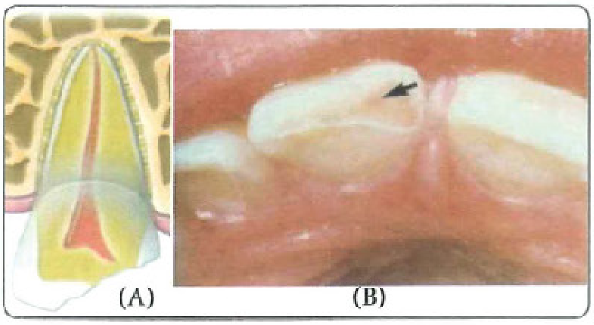


Fig. 7. Crown fracture result in loss of enamel and dentin A pink spot can be seen ,but if there is no direct exposure, the fracture is referred to without pulp involvement.

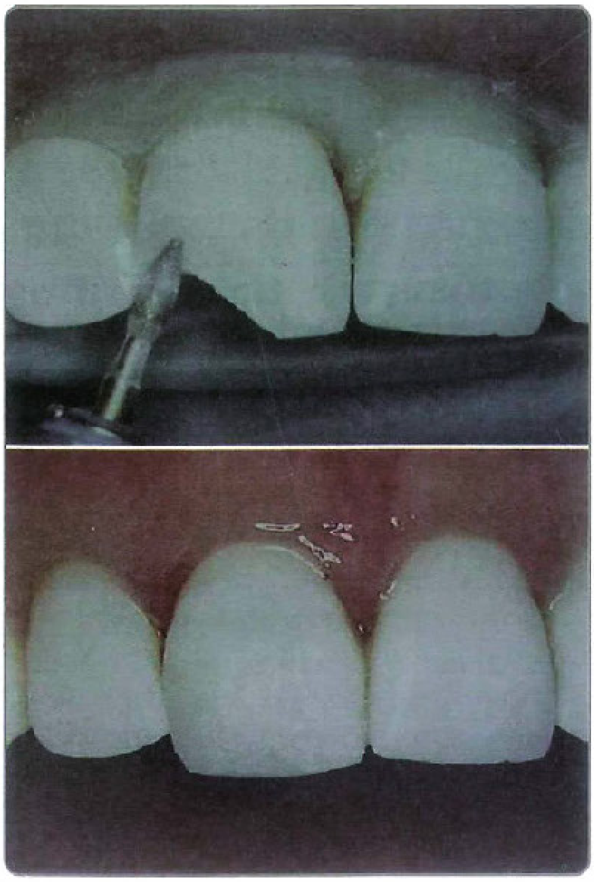


Fig. 8 Uncomplicated Crown fractures (no pulp exposure); the crown is repaired with bonded composite

Diagnosis

- Patient complain of sensitivity to air, cold and hot
- Pulp status using sensitivity tests
- Periodontal ligament status

Emergency treatment

- Seal dentinal tubules with Ca(OH)2, this will disinfect the fractured dentinal surface and stimulate closure of dentinal tubules –to be less permeable to noxious stimulant.
- Restore with dentin bonding agents, and create a tight seal.
- Reattach If the fracture crown fragment is available.

Prognosis and follow up :

Routine 3,6,12 months- up to 5 years

Factors affect prognosis.:

- Proximity to pulp
- Exposed dentine area
- Time elapsed

Complicated Crown fractures (with pulp exposure)-(0.9-13%)(Fig 9)

The degree of pulp involvement varies from a pin point exposure to a total de-roofing of the coronal pulp.

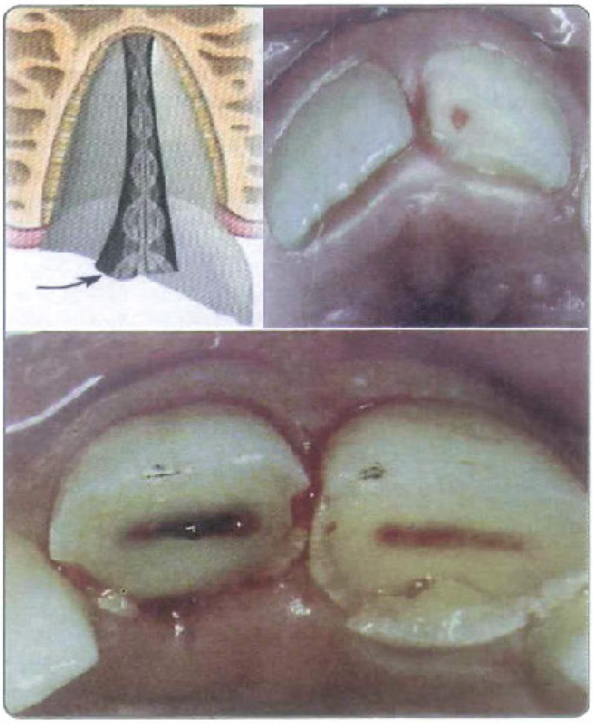


Fig. 9. Crown fractures with pulp exposure- a pin point exposure - total deroofing of the coronal pulp.

Diagnosis:

Chief complaint: Fracture of the crown, bleeding.

Clinical Examination reveals an exposed pulp.

Pulp reaction (Fig 10)

The initial pulp reaction is hemorrhage at the site of the pulp wound. Next, a superficial inflammatory response occurs, followed by either destructive (necrotic) or proliferative (pulp polyp) reaction.

Also, because the fractured surface is usually flat, allowing salivary rinsing with little chance of impaction of debris, in the first 24 hours the inflammation does not extend more than 2 mm into the pulp.

While in the presence of bacterial contamination local pulp necrosis and a slow apical spread of pulpal inflammation occur.

Factors affecting treatment planning and prognosis

- Stage of tooth development and pulp status
- Time between trauma and treatment
- Attachment damage
- Restorative treatment plan

Every effort should be directed toward keeping the vitality of the pulp. This is particularly important in immature teeth in which continued root development will result in a stronger tooth that is more resistant to fractures than one with thin dentin walls and open apex.

Treatment options

The line of treatment chosen depends on the extent of the fracture, time between injury and treatment as well as the stage of root development.

1- Vital pulp therapy *techniques of Apexogenesis.*

   Pulp capping (immature, vital, pinpoint exposure, less than 24hour).

   Pulpotomy, (immature, vital, bigger exposure, more than 24hour)

   This is also applied to mature tooth that can be restored with acid etched composite.

2 Conventional RCT

   Preceded by Apexification (immature, non- vital)

   Not preceded by Apexification (mature, definitive treatment)

3- Regeneration of pulp tissue

4- Surgical treatment

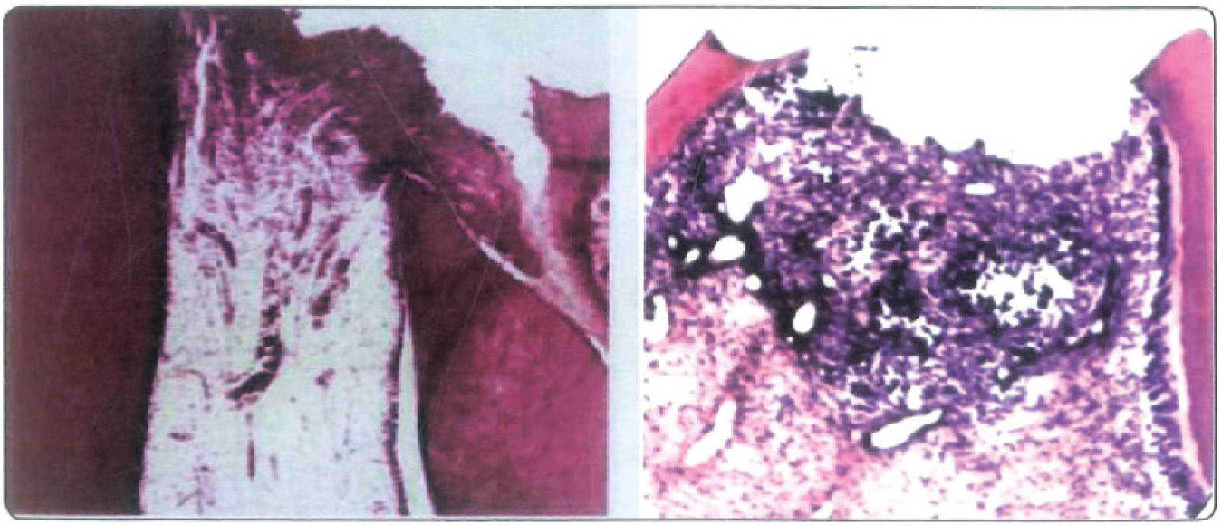


Fig. 10. Superficial inflammatory response occurs at the exposure site (24 hours). Later a proliferative (pulp polyp) reaction (48hours) is present.

Treatment methods

Vital Pulp Therapy

Apexogenesis; Treatment of a vital pulp in an immature tooth to permit continued root growth and apical closure.

Criteria for case selection for Vital Pulp Therapy and *requirement for success*

1- Treatment of a healthy pulp (within 24hour)

   The tooth must be asymptomatic with absence of spontaneous pain, pain on percussion, no periapical lesion and controllable hemorrhage.

2- A bacteria-tight seal

3- A proper pulp dressing

Materials used for pulp dressing in vital pulp therapy

1- Calcium hydroxide (Ca (OH)2

2- Mineral Trioxide Aggregate (MTA)

3- Newer generation bioceramic materials that have the same positive properties as MTA but not the disadvantages. They set quickly enough for a one-visit procedure and do not discolor the tooth.

Techniques

Pulp capping (success 80%)

Superficial inflammation develops soon after traumatic exposure which might explain the low success rate, thus, if the treatment is at the superficial level, a number of inflamed (rather than healthy) pulps will be treated, lowering the potential for success.

Cvek Partial Pulpotomy (success 95%) (Fig 11)

Remove superficial inflamed pulp and allows space for sensitivity testing.

Full Pulpotomy (success 75%), sensitivity testing not possible, follow up is done radiographically

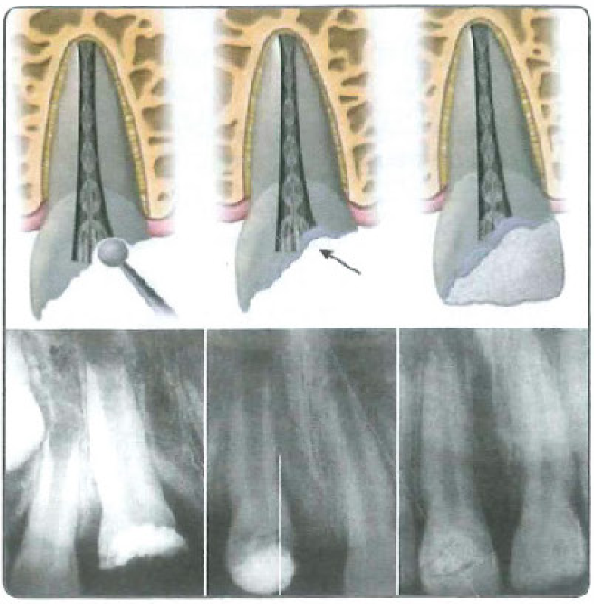


Fig 11. Cvek Partial Pulpotomy. Full (Ca (OH)2 Pulpotomy

Treatment of non-vital pulp

A non-vital immature tooth presents a number of difficulties for adequate endodontic therapy. A wide apex with no barrier to prevent the filling extrusion with a canal highly susceptible to leakage, thin dentinal wall that might fracture during and after treatment.

1- *Immature tooth: Apexification*

   It is the induction of hard tissue barrier against open apex, where this barrier provides a stop against which the root canal filling material may be condensed and confined to the root canal space.

Prognosis following Apexification

- Continuous closure of canal and apex to normal configuration.
- Apex closure, but canal remains with blunderbuss configuration.
- Radiographic evidence of barrier short of apex
- No radiographic change, but thin osteoid-like barrier provide definite stop at apex.
- No radiographic evidence of barrier and clinical symptoms of periapical lesion (failure).

Filling of the root canal and reinforcement of the thin dentinal wall

Care must be taken to avoid lateral force during filling owing to the thin root walls. Also softened filling technique is preferable. The root canal filling should be completed to the level of the formed apical barrier and not to the radiographic apex.

2- *Immature tooth: Hard Tissue Apical Barrier (Fig 12).*

Bioceramic materials as MTA has been used to create a 3 to 4mm hard tissue barrier directly after the disinfection of the canal. For MTA setting, a wet cotton pellet may be placed against the MTA and left for at least 6 hours and then the canal is filled. The filling can also be placed immediately since the tissue fluids of the open apex will provide the moisture needed for setting. The cervical canal is reinforced with composite resin below CEJ.

3- *Immature tooth: Pulp Revascularization*
Regeneration of a necrotic pulp has been considered possible only after avulsion of an immature permanent tooth. Thus, if the canal is effectively disinfected, a matrix into which new tissue could grow is provided, and the coronal access is effectively sealed, regeneration should occur as an avulsed tooth (Fig 13).

***Regeneration of pulp tissue in a necrotic infected tooth with apical periodontitis*;**

1. The canal is disinfected (without instrumentation, with 5.25% NaOCl.
2. Provide matrix for new tissue growth (blood clot to the level of CEJ, effective coronal seal: MTA and bonded resin above it.

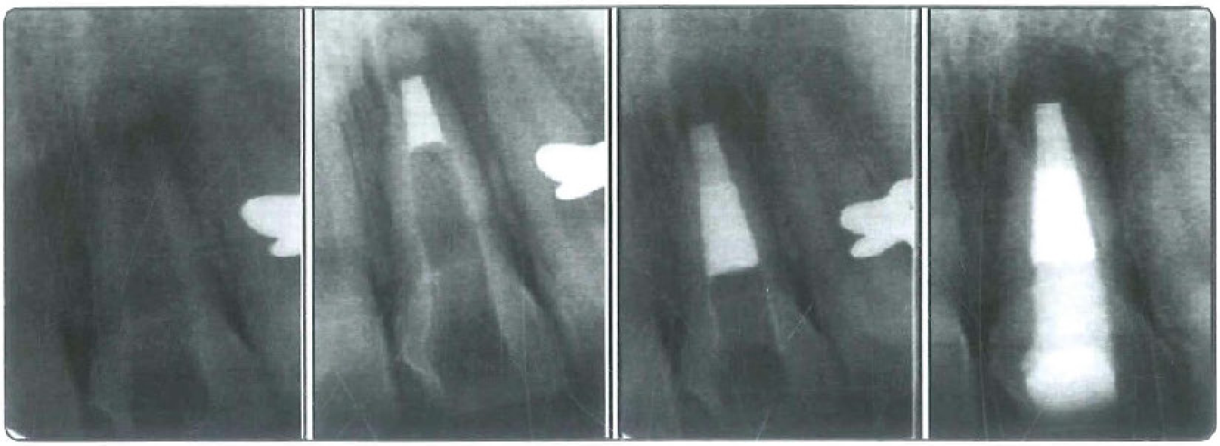


Fig. 12. MTA apical barrier for a non vital immature tooth

Fig. 13. Revascularisation of an immature nonvital pulp

3. Tri antibiotic paste for 4 weeks: Ciprofloxacin, metronidazole, minocycline).

   If after 3 months follow up shows no regeneration, apexification could be attempted.

Mature teeth

Traumatized mature teeth are routinely treated endodontically in the same way as non traumatized teeth.

Root Fracture (3% or less)

This injury implies fracture of cementum, dentin and pulp.

The fracture might be complete / incomplete having single line of fracture or multiple lines .Also the fracture line could be horizontal, vertical or diagonal (chisel).

Diagnosis

- Clinical mobility of the tooth.
- Displacement of the coronal segment and its extent is usually indicative of the location of the fracture and vary from none (apical fracture),to severe (cervical fracture).
- Presence of pain on biting and tenderness to palpation over the affected root.
- *Radiographic examination;* it is important to take at least three angled radiographs *(45°, 90°, 110°)* so that at least at one angulation the x-ray beam will pass directly through the fracture line and make it obvious (Fig 12).
- The use of cone beam is helpful in properly detecting the fracture site and extent.

Treatment

No mobility or displacement ... no treatment.

Mobility or displacement ... emergency treatment involves repositioning of the segments in as close proximity as possible and splinting for 2-4 weeks with functional splint, follow up 3, 6, 12 month and yearly for 5 years (Fig 13).

Following initial treatment by reduction and stabilization, repair by calcific and/or fibrous deposition is very likely.

About 80% of properly treated root fractures heal successfully.

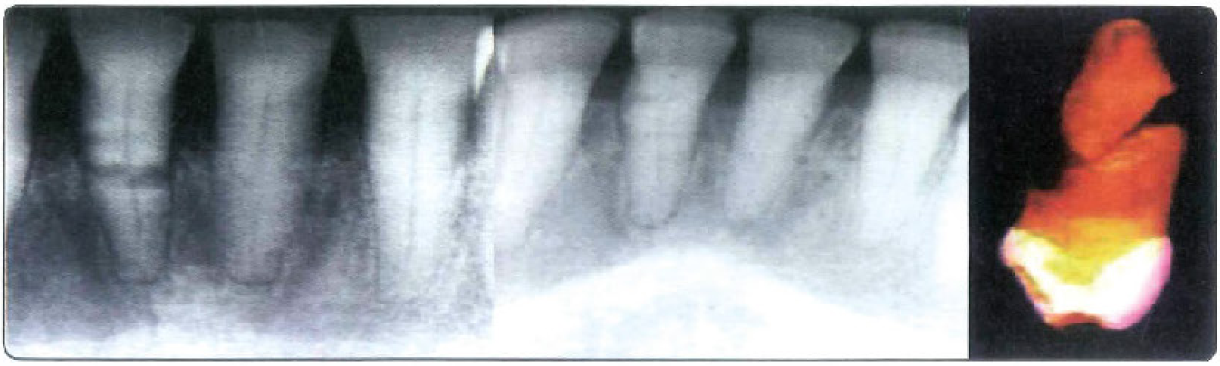


Fig. 14. Different angled radiographs produce different radiographic images

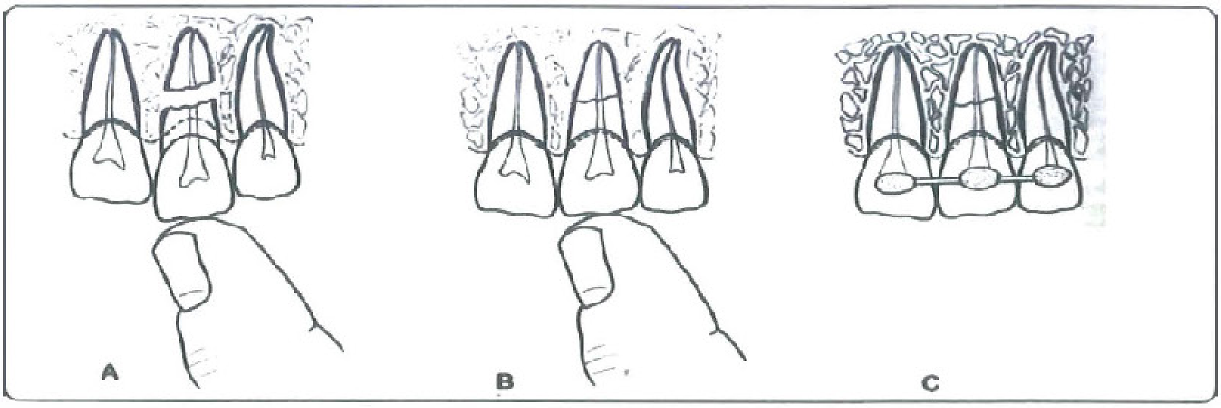


Fig. 15 Repositioning of the fractured segments and splinting for 2-4 weeks

Healing patterns for root fracture

- Healing with calcified tissue (callus union).
- Healing with inter-proximal connective tissue.
- Healing with inter-proximal bone and connective tissue.
- Inter-position of granulation tissue without healing (Fig 16).

Prognosis depends on;

- The degree of dislocation and mobility of the coronal segment. Increased dislocation decreases prognosis.
- Communication between the fracture line and the gingival sulcus.
- Fracture location, whether coronal, at the middle or apical, apparently matters less as long as it is not too close to the alveolar crest
- Quality of treatment; prognosis increases with early treatment, close reduction of root segments and semi-rigid splinting.
- The stage of root development matters in root fractures. The more immature the tooth, the better the ability of the pulp to promote apical closure.

Complications

Pulp necrosis occurs in 25% of root fractures, usually in the coronal segment with the apical segment remaining vital.

Root canal obliteration is not uncommon if the root segments remain vital.

Treatment of complications (Fig 17):

- Root canal therapy (RCT) of coronal segment and no treatment of apical segment if the apical segment is vital.

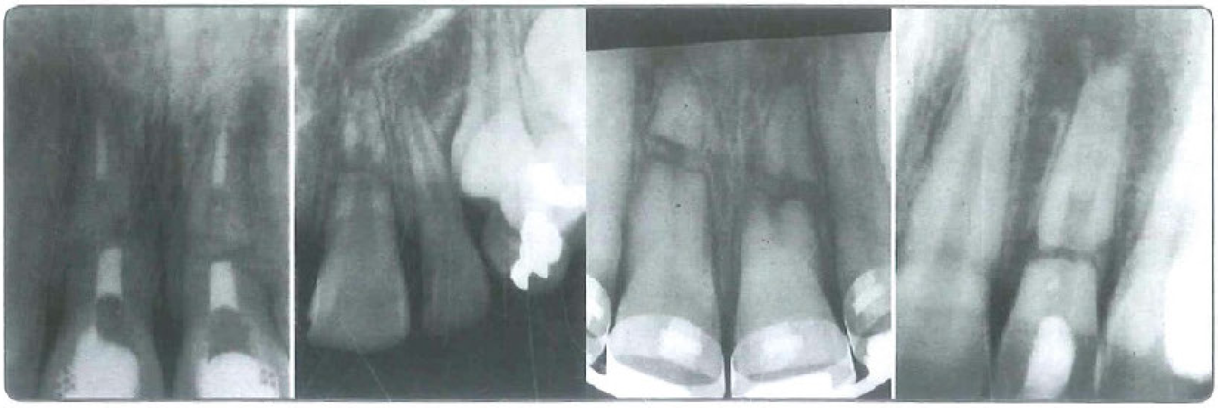


Fig. 16 Healing of root fracture ;Calcified tissue, Connective tissue, Connective tissue and bone, No healing

Fig. 17. RCT of coronal segment only, other with surgical removal of necrotic apical segment-calcific metamorphosis

- RCT for both segments, in rare cases when both parts are necrotic.
- RCT of both segments followed by endodontic stabilizer. However, this treatment weakens the root.
- RCT of coronal segment and surgical removal of necrotic apical segment, if the coronal part is long enough to provide adequate periodontal support.
- RCT of coronal segment and surgical removal of apical one with Endodontic Endo -Osseous implant.
- The coronal segment in the previous cases could be treated as an immature root and hence apexification and MTA barrier could be applied to enhance closure of the apical widest part.
- Root extrusion, if the fracture is at the coronal third of the root and the amount of the crown left is very mobile.
- Extraction

Crown/Root Fracture (Fig 18)

Crown root fracture involve enamel, dentin and cementum, the pulp may or may not be involved.

The fracture line could be either short and chisel type or long and extending the full length of root up to the apex. it could be complete or incomplete and act like cracked tooth syndrome.

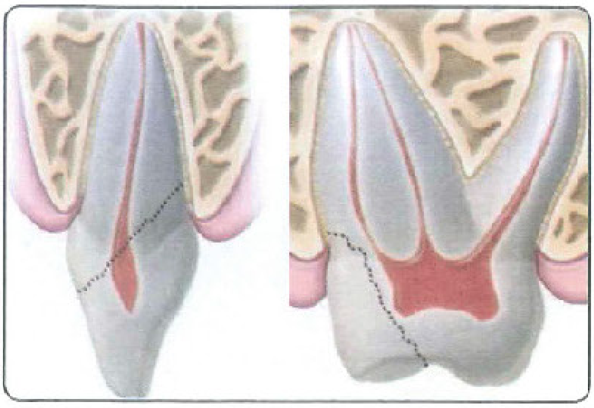


Fig. 18. Crown root fracture with pulp exposure, without pulp expsure

Also this type of fracture could also develop especially in posterior teeth

- During obturation, due to excessive force.
- During post placement.
- Large-sized restoration
- Incidence: 5 % higher incidence with crack tooth syndrome and vertical splitting (fracture) of endodontically treated teeth.

Diagnosis:

- Usually chisel type fracture with a single or multiple fragments below the lingual gingiva.
- The fragments may be firm or loose and attached only by the periodontal ligament. Mobility or displacement with pain on manipulation.
- Bleeding or lateral abscess opposite fracture site might be present.
- Transillumination could be applied to detect incomplete fracture.

Emergency Treatment

These fractures are first treated periodontally to ensure that a good margin for restoration is possible.

- If incomplete fracture ... confine it.
- If complete fracture ... all loose fragments are removed, then evaluate remaining tooth structure.
- If the remaining apical part is restorable (apical extent) ... treat as complicated or uncomplicated crown fracture with crown lengthening or orthodontic therapy (root extrusion) (Fig 19).
- If irrestorable ... extract.

Follow up and prognosis

Routine follow up as complicated and uncomplicated crown fracture

Fig. 19. Removal of the loose fractured part followed by forced eruption of the tooth using a horizontal wire

Tooth luxation injuries 30 to 44% of dental injuries (Fig 20)

The most common type of injury.

Damage occurred to the PDL and cementum ranging from localised tear to generalised damage .Apical neuro vascular supply is also affected due to severance of blood vessels entering the root apex.

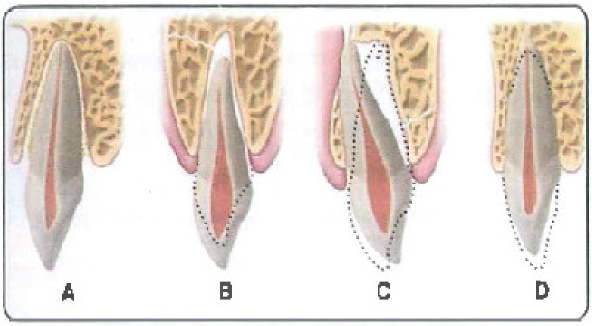


Fig. 20. Subluxation, extrusive luxation, lateral luxation intusive luxation

Concussion: Implies no displacement,normal mobility with pain on biting and sensetivity to percussion.

Subluxation: Implies pain on biting and sensetivity to percussion, increased mobility,no displacement.

Lateral luxations: Implies displacement labially, lingually, distally or mesially (Fig21)

Vertical luxations; The tooth is partially out of its socket and mobile, include;

Extrusive luxation; Implies displacement in a coronal direction

Intrusive luxation; Implies displacement apically into the alveolus.

Fig. 21. Lateral luxation with labial displacement

Diagnosis and emergency treatment

The clinical descriptions of luxation injuries should be sufficient to make the initial diagnosis. However, pulp status must be continually monitered until a definitive diagnosis can be made .

Although the initial radiograph will not diclose the pulpal condition, it serves as a basis for comparison of follow up radiograph to detect any resorption internally or externally.

Consequences of pulpal damage

A- Pulp canal obliteration (Fig 22)

Pulp canal obliteration is common after luxation and its frequency appears to be inversly proportional to pulp necrosis.

Usually diagnosed within the first year after injury.More frequent in teeth with open apex and in teeth with extrusive and lateral luxation or that which were rigidly splinted.

Fig. 22. Canal obliteration (yellow tooth)-complete root canal calcification

B- Pulp necrosis

Following injury pulp necrosis can develop and lead to infection of the root canal. The type of injury and the stage of root development are the most important factors.

C- Pulp space infection and root resorption

Microbial toxins pass through dentinal tubules and stimulate an inflammatory response in the PDL and cementum with external inflammatory root resorption as the consequence.

Also coronal necrotic pulp toxins pass via DT stimulate pulp inflammation of apical pulp and stimulate an internal inflammatory root resorption.(fig 23)

Fig. 23. Inflammatory root resorption caused by a pulp space infection.

Treatment

Concussion and subluxation: follow up; obliteration, necrosis.

Routine follow up with thermal (Co2 snow and electrical tests (elderly pt) at the time of injury and at weeks 3,6,12 months and yearly. May need stabil-ization (2-3 weeks). Transition from –ve to +ve response of trumatized pulp is a sign of healthy pulp.

Lateral and extrusive luxation; Need immediate repositioning and splinting for 2-6 weeks.

Root canal treatment for prevention of pulp space infection: attention 7 to 10 days post injury

a) Reestablish the vitality of the pulp.

b) Prevent root canal infection by root canal treatments at 7 to 10 days.

A creamy mix of calcuim hydroxide is used as intracanal dressing for 1-6 months,especially if RCT is initiated later than 10 days post injury,as external inflammatory root resorption may develop.

$Ca(OH)_2$ kills bacteria and neutralize endotoxins.

Revascularization in a young patient if indicated (foramen >1 mm) and follow up radiographically.

Intrusive luxation (Fig 24): most destructive, immature root may revascularize and are less likely to lose vitality, while in mature tooth ,pulp necrosis develop so, the tooth is gradually repositioned (orthodontically or with sudden forceps adjustement). Then, root canat treatment should be initiated.

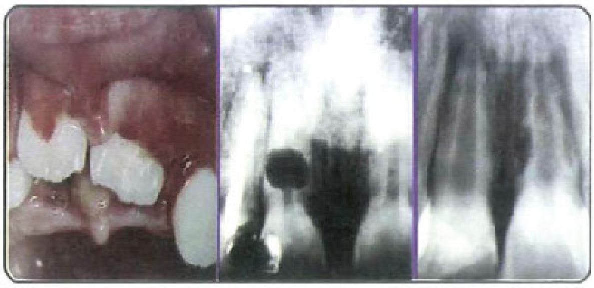


Fig. 24. Intrusive luxation-internal and external resorption

Tooth Avulsion

An avulsed tooth is completely out of its socket and known as extra-articulation. 15% maxillary central incisor is the most involved tooth due to its location and conical root. Damage to the attachment apparatus that occurred during the initial injury is unavoidable but usually minimal. Therefore, all efforts are made to minimize necrosis of the remaining periodontal ligament while the tooth is out of the mouth. Pulpal sequelae are not a concern initially and are dealt with at a later stage of treatment.

Factors affecting treatment

1- Extraoral time: the sooner, the better.

2- Tooth handling: do not scrub

3- Storage medium is critical to maintain the periodontal ligament in a vaiable state. Ideal is the socket followed by Via Span, HBS, milk, saline, saliva and then Water.

Treatment

1- **Emergency treatment at the accident site:**

Aim is to prevent dryness of the periodontal membrane.

- Replace the tooth in the socket, partly into the socket.
- Then let the patient bite down gently on a piece of cloth such as a handkerchief to move the tooth back into its normal, or nearly normal position.
- Bring the patient to the dental office right away to complete the treatment of replantation.
- or place in an appropriate storage media.

2- **Emergency treatment at dental office**

Aim is to preserve the viability of the periodontal membrane (fig 25).

-Clinical and radiographic examination of the socket of the avulsed tooth.

Debris removal with gental saline rinsing .If a blood clot is present, it is gently suctioned with no curettage to the socket.

Extraoral dry time <60 minutes (optimum time 15-20 min)

Closed apex: rinse with saline or water, replant, functional splint by acid etched composite. *Open apex (revascularization might occur)*:soak in minocyclin (1mg/20ml saline) 5 min, remove debris, replant.

Extra oral dry time > 60 minutes

Closed apex: remove periodontal ligament by placing in etching acid for 5 min, soak in 2% stannous flouride for 5 min, replant.

Emdogain (enamel matrix protein): makes root more resistant to resorption, stimulate peridontal ligament formation.

Open apex: Replant? If yes do as closed apex and endodontic treatment performed outside, better than long term Apexification..

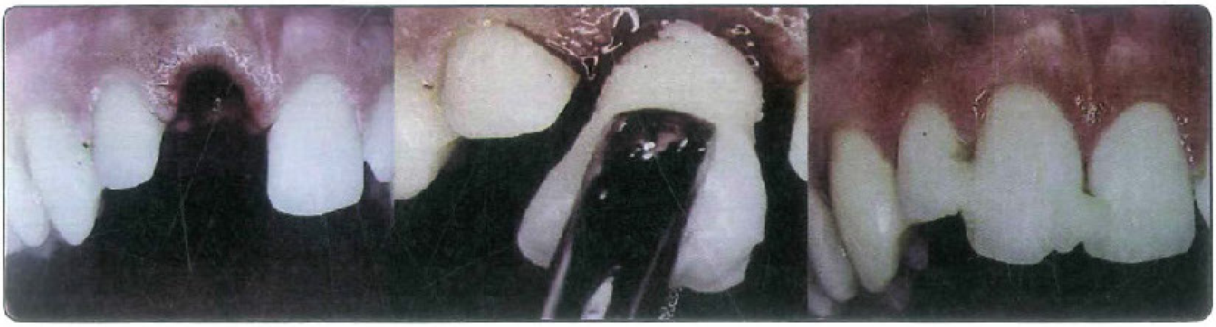


Fig. 25. The socket was rinsed with saline or water,tooth replanted, and functionally splinted.

Clinical management of the avulsed tooth

(Adjunctive therapy)

Systemic antibiotic: at emergency visit till splint removal for 7 days ,to prevent bacterial invasion of necrotic pulp and subsequent inflammatory resorption.

Tetracycline: (decrease root resorption) affect motility of osteoclasts and reduce effectiveness of collagenase.

Chlorhexidine rinse, analgesics and Tetanus booster.

Splinting

Semirigid (physiologic) fixation for 1 to 2 weeks is recommended

3- Second Visit (1-2weeks after emergency visit)

Extraoral dry time < 60 minutes

Closed apex: endodontic treatment, may use CaOH or Ledermix (corticosteroid & tetracycline): move via dentinal tubules and shut down inflammatory response. Open apex: look for evidence of revascularization.

Extraoral dry time > 60 minutes

Closedapex: endodontictreatment, mayuseCaOH or Ledermix paste to prevent external resorption. Open apex: apexification

Temporary restoration: at least 4mm depth.

Root filling visit: at 7-10 day or later if external resorption develops.

Permanent restoration and follow up care for 3, 6 months, yearly for 5 year .

Sequelae of replantation (Fig 26):

- Healing with normal periodontal ligament.
- Surface resorption; small superficial cavities in cementum than dentin, that heal by secondary cementum .
- Ankylosis; Replacement resorption; it is a very slow and continuous process of resorption of both cementum and dentin and replaced by bone,untill loss of tooth.

  If not arrested –ankylosis resorption of cementum occurs and is replaced by bone and then transient resorption will stop.

  If it occurrs during the jaw growth period, the tooth may be in infra-occlusion.
- Inflammatory resorptions radiographically appear as a bowl shape resorptive area.

Fig. 26. Replacement resorption -Inflammatory resorption

Chapter review Questions

1. Classify traumatic dental injuries? Describe the clinical and radiographic features of an uncomplicated crown fracture and its treatment options.
2. Mention the factors affecting treatment planning and prognosis of a complicated crown fracture? Describe the methods used for managing this fracture.
3. Describe the diagnostic tests and procedures used in examining root fractures. Mention the treatment options for those fractures, their healing patterns, prognosis and complications.
4. Classify tooth luxation injuries describing the possible short and long-term responses of pulp to them.
5. Describe the emergency treatment strategies for an avulsed tooth. Mention management considerations of replantation of this tooth and its sequelae.
6. Describe the difficulties encountered during treatment of a traumatized immature tooth with a complicated crown /root fracture. Analyze various treatment options.

References

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc., 2008.
- Hargreaves KM. Cohen S Cohen's Pathways of the Pulp. 10th ed. Mosby El Sevier, 2011.
- Walton RE, Torabinejad M. Principles and practice of Endodontics. 4th edition W.B. Saunders company, 2009.
- Feliciano KM, de França Caldas A Jr.A systematic review of the diagnostic classifications of traumatic dental injuries. Dent Traumatol. 2006 Apr;22(2):71-6.
- Zaleckiene V, Peciuliene V, Brukiene V, Drukteinis S. Traumatic dental injuries: etiology, prevalence and possible outcomes. Stomatologija. 2014;16(1):7-14.

19

Cracks and Fractures

Nehal Nabil Roshdy

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify different forms of tooth cracks and fractures
2. Diagnose cases of split cusp/split tooth and settle a treatment plan for any of them.
3. Report different clinical manifestations of VRF
4. Formulate a differential diagnosis between deep periodontal pocket and VRF pocket
5. State the predisposing factors to the occurrence of VRF

Chapter Outline

INTRODUCTION

Root cracks and fractures can be two of the most frustrating aspects of endodontic and restorative dentistry. The diagnosis can be difficult; the symptoms can be either vague or specific, yet insufficient for a definitive diagnosis; the radiographic evaluation can be evasive. Prevention of a potential crack or fracture is a fundamental principle, and early detection is imperative. The clinical management mainly depends on its extent.

Tooth fracture is commonly associated with impact trauma e.g. A car accident, a fall from a bicycle and an accidental blow to the face. These types of traumatic fractures mainly occur in the anterior segment of the mouth. *(See Chapter traumatic Dental Injuries)*

In contrast, the cracks and fractures are often associated with UNOBSERVED TRAUMA which is a traumatic event that the patient cannot remember. The cracks and fractures are frequently the result of an accumulating, unobserved trauma resulting from either normal or excessive occlusal forces that are repetitively applied without the patient's awareness.

DIAGNOSTIC CHALLENGE

There are three categories of cracks and fractures: cracked and fractured cusps, cracked and split teeth, and vertical root fractures. Each is often undiagnosed or misdiagnosed for a relatively long time.

However, because of the wide variety of clinical presentations from cracks to fractures, the diagnosis is less straightforward. None of the three entities necessarily exhibits a radiographic manifestation in the early stages, depriving the dentist of one of the most objective diagnostic tools. Symptoms may be present for several months before an accurate diagnosis is made, which may be frustrating for both the patient and the dentist causing the patient to develop a subsequent loss of confidence in the dentist. The final diagnosis is typically reached at a relatively late stage of these conditions, often after complications have already occurred. Complications may include a catastrophic fracture of the tooth or cusp or significant periradicular bone loss associated with a vertical root fracture as seen by radiographic examination.

FRACTURE MECHANICS

Crack is defined as a partial discontinuity in a material that may propagate and eventually lead to a complete discontinuity, known as a fracture.

A cracked tooth may be so called until a final fracture occurs that separates the tooth into two parts, a condition termed a split tooth. Similarly, microcracks may appear in the radicular dentin of an endodontically treated tooth, and these cracks may propagate with time until a vertical root fracture occurs, where the full thickness of the dentinal wall shows discontinuity: a through and-through fracture.

CRACKED AND FRACTURED CUSPS

Definition

A cracked cusp: is characterized by a crack between a cusp and the rest of the tooth structure, to the extent of allowing microscopic flexure upon mastication. This crack typically does not involve the pulp. However, with time, the crack may propagate, resulting in a fractured cusp. (Fig 1)

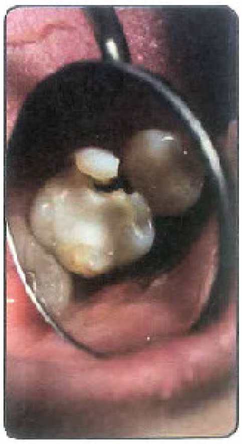


Fig. 1. Fractured cusp

Diagnosis:

Patient History:

- The patient will report a sharp pain when chewing, to the extent of not being able to chew on the side on which the crack occurred.
- The patient will also often state that the condition existed for a relatively long time and that his dentist could not find the source.
- The patient often has difficulties determining the specific location of the discomfort. Because the pain has a pulpal origin, the patient's proprioception may not be accurate. Occasionally, the pain upon chewing may radiate to nondental locations on the same side of the face.

Clinical Manifestations :

(A) Early Manifestation :

Sharp pain upon chewing, although the affected tooth may not be sensitive, or selectively sensitive to percussion. The tooth is vital, and its response to a cold stimulus may be normal; but with time, this response may resemble a pulpitis, which may be either localized or referred to other odontogenic or nonodontogenic locations.

Cracked cusps are often associated with extensive occlusal restorations, but also may be present in intact teeth or teeth with smaller restorations.

(B) Late Manifestation:

With time, the crack propagates resulting in a fractured cusp. If the fracture line occurs supragingivally, the fractured portion will simply separate from the tooth. However, if the fracture line extends subgingivally, the periodontal ligaments will retain the fractured cusp.

It is possible to move the cusp by wedging a sharp explorer into the fracture line, making the fractured cusp more visible. Often, from continued mastication, acute and localized pain may emerge secondary to the movement of the fractured fragment in the coronal PDL. The pulpal pain that is typical at the earlier stage (the cracked cusp) will resolve once a complete fracture occurs.

Diagnosis A cracked cusp can be diagnosed, to a large extent, based on the patient history.

a) To locate the affected tooth, a biting test should be performed using a Tooth Slooth or a similar device. The patient will state that this sensation has reproduced the sensation of the chief complaint. (Fig.2)

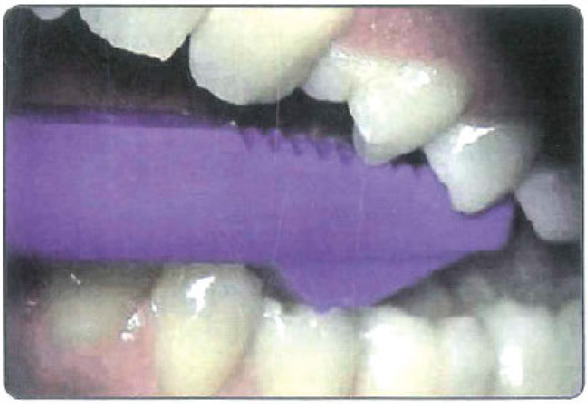


Fig. 2. Biting on a Tooth Slooth

b) Magnification with loupes or an operating microscope can be helpful when looking for a crack.

c) Transillumination may assist in revealing the crack line, if the tooth does not have an extensive intracoronal restoration or upon the removal of the restoration. The light source should be intense and with small dimensions; it is applied to the tooth at the area of the suspected cusp fracture, after darkening the room. The light penetrates the tooth structure up to the crack, leaving the part beyond the crack relatively dark (**Fig.3**)

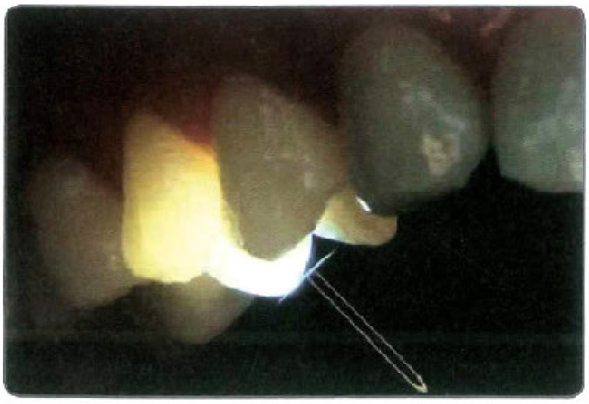


Fig. 3 Transillumination

Treatment Planning:

A) Cracked Cusp Treatment: consist of protecting the affected cusp from occlusal forces, both to prevent pain while chewing and to prevent the propagation of the crack into a full fracture. A full-coverage crown, onlay or bonded composite restorations are recommended.

Endodontic treatment is indicated only if signs and symptoms of pulpal pathosis are observed, or as an elective treatment which is necessary for prosthetic reasons. In cases of little or no remaining coronal tooth structure, after the removal of the cracked cusp and associated restoration. Occlusal reduction of the tooth should be performed as soon as possible to remove the tooth from active occlusion. The patient should be instructed to be careful when chewing until the tooth is restored with a crown.

B) Fractured Cusp Treatment: depends on the amount of tooth structure remaining.

If the missing part is limited in size, then the conservative restoration of a bonded composite resin may be indicated to cover the exposed dentin.

If the missing part is large, a full crown or an onlay may be necessary. In certain cases, when cracked cusps are found in intact teeth or in teeth with no extensive restoration,

CRACKED AND SPLIT TEETH

Definition

A cracked tooth exhibits a crack that incompletely separates the tooth crown into two parts. If the crack is allowed to propagate longitudinally, the tooth will eventually fracture into two fragments, resulting in a split tooth.

Diagnosis

In cases of a cracked tooth, the patient history may be similar to that for a cracked cusp: sharp pain upon mastication and prolonged failure of the dentist to diagnose the source of the pain. Often it is challenging for the practitioner to determine the location of the offending tooth. With time, the patient reports having a sharp pain and experiences great sensitivity to cold stimuli; then at a later stage, the patient reports that the pain has subsided. These observations are consistent with pulpitis or pulp necrosis, which may develop in the affected tooth with time.

Clinical Manifestation :

(A) Early Manifestation :

Cracked teeth may have extensive restorations with a weakened crown, or they may have minimal or no restorations. A cracked tooth begins with a crack in the clinical crown, which may gradually propagate in an apical direction. Such cracks typically run in the mesiodistal direction, often splitting the crown into the buccal and lingual fragments.

Vitality: In the early stages, the tooth is vital and painful to mastication. The pain is sharp, to the extent that the patient is unable to chew on the affected side. This condition may persist for an extended period of time. The pain may be localized or referred to any tooth, maxillary or mandibular, on the same side of the mouth. Pulp testing may be normal or indicative of increased sensitivity to cold stimuli.

Radiographic Findings: No radiographic manifestations are present at these early stages, as the crack is microscopic and runs perpendicular to the x ray beam.

Percussion: The affected tooth may or may not be sensitive to percussion at this point,

(B) Late Manifestation

The late manifestation of a cracked tooth includes pulp involvement with eventual loss of pulp vitality and apical propagation of the fracture, resulting in a split tooth.

Pulp involvement occurs more often in cases of centrally located cracks (i.e., extending from marginal ridge to marginal ridge through the central fossa). These centrally located cracks commonly affect the roof of the pulp chamber at a later stage. Consequently, pulp vitality may be compromised and later lost due to bacterial penetration through the crack.

The sharp pain upon mastication disappears once pulp vitality is lost. Moreover, apical periodontitis in an apparently intact molar may be a late manifestation of an untreated case of a cracked tooth.

When pulp necrosis occurs, the radiographic manifestation may be an apical radiolucency, which is indistinguishable from that of apical periodontitis.

When this split occurs, the resulting parts of the tooth may be movable by wedging a sharp explorer into the fissure. Later, more evident movement of the parts may be observed. The radiographic presentation at such a late stage may eventually develop into a diffuse radiolucency surrounding the root. At this late stage, creation of narrow isolated deep periodontal pockets located mesially or distally occurs and, if adjacent teeth are present, they will be difficult to detect.

Cracked and split teeth may present with a variable signs and symptoms that are potentially confusing. Only by being aware of the process from early to late manifestations can clinicians interpret these signs and symptoms.

A definitive combination of factors, signs, and symptoms that, when collectively observed, allows the clinician to conclude the existence of a specific disease state is termed a syndrome. However, given the multitude of signs and symptoms that cracked roots can present with, it is often difficult to achieve an objective definitive diagnosis. For this reason, the terminology of cracked tooth syndrome should be avoided.

DIAGNOSIS

Early detection is imperative to resolve the patient's symptoms as well as increasing the prognosis.

Diagnostic adjuncts:

- The use of the Tooth Slooth device may not provide a clear result, if the tooth parts are rather stable.
- Asking the patient to chew on a cotton roll may reproduce the pain, but this method may not indicate the source of the pain (maxillary or mandibular). Anesthetizing the suspected tooth, followed by asking the patient to chew again on the cotton roll, may further confirm the diagnosis and finally differentiate the origin as a mandibular or maxillary tooth.
- Magnification using either loupes or an operating microscope can be helpful for detecting a fracture line.
- Dyes, such as methylene blue or tincture of iodine, applied either to the outer surface of the crown or to the dentin after the removal of an existing intracoronal restoration, can be helpful for visualizing the crack.

- Transillumination can also be applied to the suspected tooth (effective in giving a straightforward diagnosis, if the tooth has no restorations).
- At a later stage(Split tooth), wedging of a sharp explorer into the fracture line will provide a clear diagnosis.

Generally speaking, the diagnosis of a crack in a tooth can be difficult especially when there are signs and symptoms of a pulpitis or necrosis, it is difficult for the clinician to determine the source that initiated the signs and symptoms. So, it has to be considered that in the case of a problematic tooth with no apparent reason for the pulpitis or necrosis, like a tooth with minimal or no caries, restoration, or trauma, a crack or fracture must be considered. However, the patient should be advised of a potential decrease in the endodontic or restorative prognosis.

Etiology

Masticatory forces are the cause of cracked teeth e.g chewing on coarse food, chewing ice, unexpected chewing of a hard object (e.g., a cherry pit), bruxism or clenching of the teeth and occlusal prematurities.

Certain teeth are more prone to developing cracks, such as mandibular second molars and maxillary premolars.

Treatment Planning

Cracked Tooth

Once diagnosed, the patient should be informed that the prognosis is reduced or questionable and that long-term follow-up will be required. The principal goal of treatment is to protect the tooth from crack propagation and improve the comfort while chewing. Both goals can be achieved by placing an orthodontic band around the tooth or placing a provisional crown, allowing the clinician to evaluate the extent of pulp involvement by checking whether the pulpal symptoms subside in response to the intervention. However, endodontic treatment followed by placement of a permanent crown usually resolve the symptoms.

Split Tooth

When the tooth is split either through its whole length or diagonally (Fig. 4), extraction is typically the only treatment option.

However, if the fracture line is such that the split results in large and small segments, and if the removal of the small fragment preserves enough tooth structure that is restorable, then retention and restoration of the tooth may be considered.

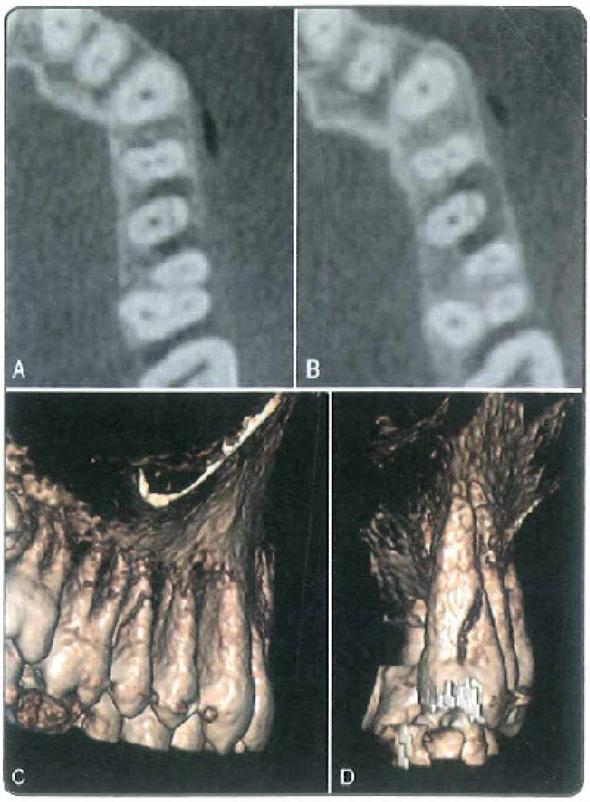


Fig. 4. Diagonally split tooth. A maxillary right second premolar presented with a mesiodistal coronal fracture. A&B: CBCT axial views revealing a mesiodistal fracture at two different levels, with associated mesial and distal bone loss. C&D: the three-dimensional reconstruction clearly reveals the nature and direction of the fracture and defined the tooth as unrestorable

VERTICAL ROOT FRACTURE (VRF)

VRF is a longitudinally oriented complete or incomplete fracture initiated in the root at any level and is usually directed buccolingually. Thus, these types of fractures do not arise from the propagation of a fracture that originated in the crown. The definition separates a VRF from a split tooth (which begins with a crack of the crown that propagates apically into the root as a longitudinal fracture).

Diagnosis

Patient History

In the case of a VRF, a patient may complain of pain or sensitivity related to a certain tooth. Sensitivity and discomfort while chewing are also common complaints. Swelling may occasionally occur in the area. There is often a long history of failing to diagnose the cause of the pain and discomfort. A history of repeated clinical and radiographic examinations that revealed no cause for the pain is also common. Often endodontic treatment, retreatment or surgical retreatment may have been attempted to reveal the accurate diagnosis. Unfortunately, such ineffective treatment attempts may only worsen the dentist-patient relationship.

Clinical Manifestations

Susceptible Teeth and VRF Location:

Vertical root fractures are commonly associated with endodontically treated teeth with or without a post. Nevertheless, VRFs can also occur in teeth with no previous root canal treatment.

The most susceptible tooth groups are: the maxillary and mandibular premolars, the mesial roots of the mandibular molars, the mesiobuccal roots of the maxillary molars, and the mandibular incisors. Vertical root fractures may progress in the buccolingual direction in these teeth and roots, which are typically narrow mesiodistally and wide buccolingually. However, VRFs may also propagate diagonally, thus affecting the mesial or distal aspect of the root.

VRFs may be initiated at any root level. They may be initiated at the apical part of the root and propagate coronally. However, certain VRFs originate at the coronal, cervical part of the root and extend apically and in other cases, a VRF may be initiated as a midroot fracture (Fig.5).

It is commonly believed that VRFs begin as microcracks at the root canal surface of the radicular dentin and gradually propagate outward until the full thickness of the radicular dentin is fractured.

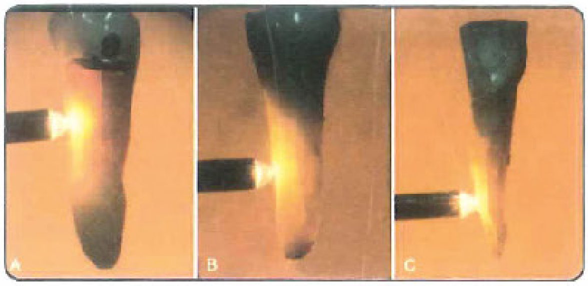


Fig. 5. Three types of VRFs. A: A coronally located VRF. B: A mid-root VRF. C: An apically located VRF

Early Manifestation

There may be dull pain or discomfort on the affected side of the tooth. Particularly, the tooth may feel uncomfortable upon chewing. As the fracture and subsequent infection progresses, swelling often occurs, and a sinus tract may be present at a more coronal position than a sinus tract associated with a case of chronic apical abscess (Fig. 6). These signs and symptoms are frequently similar to those encountered from nonhealing root canal treatment.

A deep, narrow and isolated periodontal pocket may be associated with the root, which often cannot be explained (due to inconsistency with the surrounding periodontal examination). This type of periodontal defect occurs secondary to the bony dehiscence caused by the vertical root fracture.

Fig. 6. A sinus opening opposite to VRF

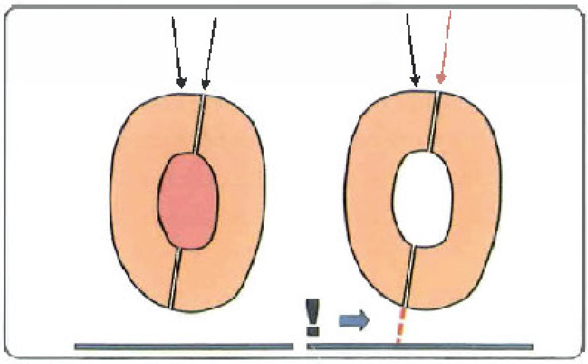


Fig. 7. Radiographic examination of filled versus empty canals. A, The buccolingual projection of a filled root will fail to detect a VRF at an early stage. B, The removal of the root filling and use of radiography at different mesiodistal angulations may reveal the VRF

Radiographic findings are unlikely because (1) the root canal filling mostly obstructs the detection of the fracture (Fig. 7), and (2) the bone destruction (still has limited mesiodistal dimensions) may be obstructed by the superimposed root structure (Fig. 8).

Late Manifestation

A longstanding vertical root fracture is easier to detect. The major destruction of the alveolar bone adjacent to the root has already occurred, allowing the VRF to be more likely revealed in a periapical radiograph. One of the most typical signs is the J-shaped or halo radiolucency, which is a combination of periapical and periradicular radiolucency (i.e., bone loss apically and along the side of the root, extending coronally) (Fig. 9).

In addition, the pocket along the fracture becomes wider and easier to detect. In longstanding cases in which the bone destruction is extensive, the segments of the root may also separate, resulting in a radiograph that clearly reveals an objective root fracture.

Importance of Early Diagnosis

Accurate diagnosis is crucial in VRF cases, allowing the extraction of the tooth or root before extensive damage to the alveolar bone can occur. Early diagnosis is particularly important when implants are a potential part of the future restorative procedure; when an extraction is performed at an early stage, the uncomplicated placement of an implant is likely.

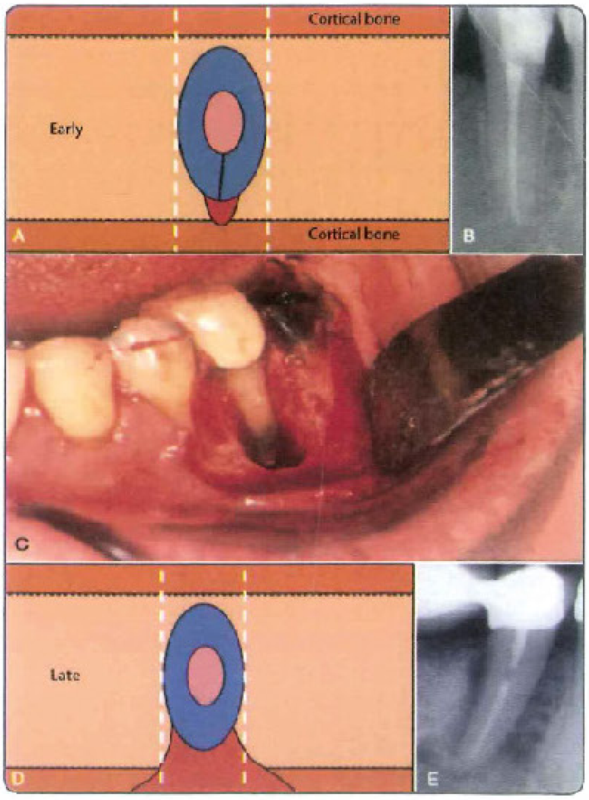


Fig. 8. Early versus late radiographic presentation of a VRF-associated bone defect. At an early stage, a bone defect (red) is not likely to be detected in a periapical radiograph, as the root will overlap with the defect (A,B). At later stages, when major damage has occurred to the cortical plate (C), the bone defect may be large enough to extend beyond the silhouette of the root (C,D) and appear as a radiolucent defect along the root (E).

Fig 9. Halo radiolucency along root

The American Association of Endodontists stated in 2008 that a sinus tract and a narrow, isolated periodontal probing defect associated with a tooth that has undergone a root canal treatment, with or without post placement, can be considered pathognomonic for the presence of a VRF.

Misdiagnosis of VRFs

Many of the clinical symptoms associated with VRFs mimic apical periodontitis or periodontal disease together with the narrow and tight pocket associated with the early stages of VRF which are difficult to detect using rigid probes make it difficult to early diagnose resulting in a delay in the accurate diagnosis or a misdiagnosis of a VRF (Table 1).

VRF Pockets

The pockets that are typical of the early stages of VRFs differ from the deep pockets associated with advanced periodontal disease.

Rigid metal periodontal probes may be ineffective in probing VRF pockets in the early stages of a VRF. A flexible probe should be used instead (Such as a probe available from Premier Dental Products (Plymouth httpMeeting, Pennsylvania)) (Fig. 11). The insertion of a probe requires the detection of the coronal opening and light pressure.

Table (1)

	The deep periodontal pockets	VRF pocket (Early stage of VRF)
Origin	Develop as a result of the bacterial biofilm that initially accumulates at the cervical areas of the tooth and the destructive host response to these bacteria.	Develop due to bacterial penetration into the fracture, triggering a destructive host response that occurs in the periodontal ligament along the entire length of the fracture. The bacteria may leak from an infected root canal; however, when the VRF extends to the cervically exposed root, the microbes in the fracture may also originate from the oral cavity.
Clinically	Wider coronally and relatively loose. The deeper part of a pocket is present at the mesial or distal aspects of the tooth. The pocket structure allows the easy insertion of rigid periodontal probes (Fig. 10).	Deep, narrow and tight pocket (see Fig.10). Where, the periodontal ligament is destroyed along the longitudinal opening of the fracture, with a limited resorption to the adjacent bone. This permits the penetration of a periodontal probe. The pocket is often located at the buccal or lingual convexity of the tooth.
Location	Affects groups of teeth	Isolated pocket adjacent to the affected tooth

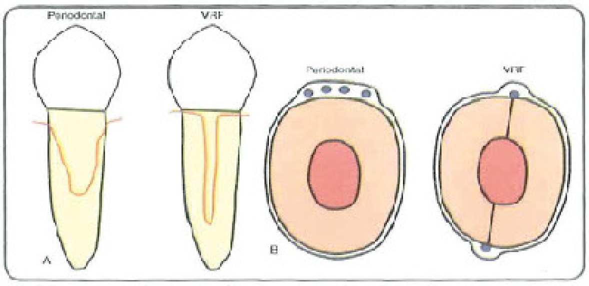


Fig. 10. VRF pocket. A, Periodontal pockets (left) are wide coronally, whereas VRF pockets (right) are narrow and deep. B, Periodontal pockets (left) are loose and allow probing at various sites, whereas VRF pockets (right) are narrow and tight.

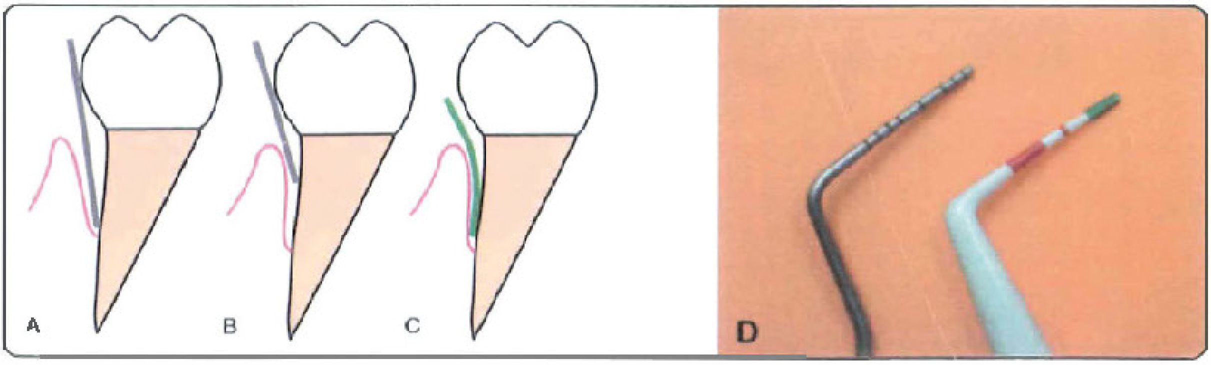


Fig. 11 Rigid versus flexible probes A, In a loose periodontal pocket, a rigid metal probe can easily reach the depth of the pocket. B, In a tight, early-stage VRF pocket, a rigid probe may be of limited value, as the bulge of the crown often prevents the insertion of the probe into the tight, deep pocket. C, A flexible probe (D) is more likely to detect VRF pockets at an early stage.

Coronally Located Sinus Tract

Sinus tracts that originate from a chronic apical abscess are typically detected at the site of least bone resistance, against the apical part of the root or in the area of the junction of the attached gingiva and the oral mucosa.

While, sinus tracts that are associated with a VRF pocket are often found in a more coronal position, as the source is not from a periapical lesion

Radiographic Features

Radiolucency in the Bone Along Root

In the early stages of VRF:

The bone resorption is limited in the buccolingual plane and any associated radiolucency may be obscured by the superimposition of the root. (Fig 8). Also, immediate radiographic detection is difficult due to the time required for bone resorption to occur or for the fractured segments to separate and be radiographically visible.

The intermediate stage of VRF:

Radiographs must be taken at different horizontal angulations to detect the bone resorption (Fig.12). This radiographic feature should be differentiated from a split tooth (where the fracture plane is typically mesiodistal, with the bone resorption occurring on the mesial or distal aspects of the root). A radiographic appearance of a thin radiolucent line extending longitudinally down the root determines a definitive diagnosis of VRF. However, it is difficult to detect and are commonly not seen in routine periapical radiographs. Therefore, once a fracture is suspected, two or three periapical radiographs should be exposed from different horizontal angulations.

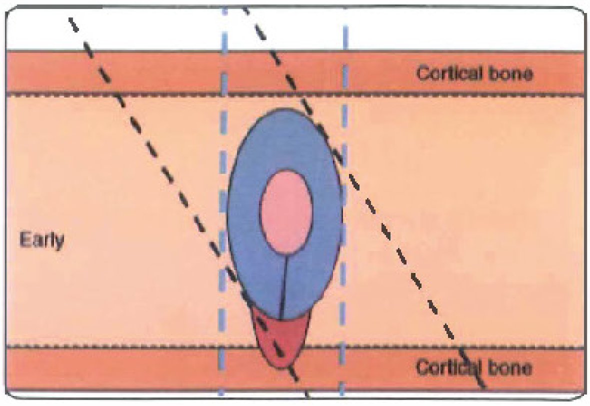


Fig. 12. Radiographs from different horizontal angulations

The late stage of VRF:

The J-shaped or halo appearance, a combination of periapical and periradicular radiolucencies, was associated with a high probability of a

VRF. An angular resorption of the crestal bone along the root on one or both sides, without the involvement of the periapical area, mimicking a "periodontal radiolucency" (Fig.9), was found in 14% of the cases.

Cone-Beam Computed Tomography in VRF Diagnosis

Modern cone beam computed tomography (CBCT) provides the privilege of studying the suspected tooth and associated bone in an axial plane. Axial views provide detailed information of the cross sectional appearance of the tooth and its surrounding bone suggesting the detection of early-stage VRF. Yet, such detection greatly depends on the resolution of the machine (i.e. the voxel size). Given that the smallest voxel size currently available for a CBCT device is about 0.075 mm, thus, CBCT imaging would not be able to visualize a root fracture unless the fracture width was greater than 0.15 mm. It should also be noted that the intracanal presence of gutta-percha or a metal post often causes artifacts that make it extremely difficult to differentiate a VRF from such artificial lines.

Exploratory Surgery

When clinical and radiographic evaluations are equivocal in detecting a suspected vertical root fracture, exploratory surgery may be indicated. Where, a full-thickness flap is raised and the granulation tissue is removed, a VRF is often visualized (Fig 8). The bone resorption pattern associated with a VRF is mostly seen as a bony dehiscence, with the greater bone destruction present on the buccal cortical plate located over the offending root. In a small percentage of the cases, fenestration can also be seen. Furthermore, it has been shown that the longer a VRF-related infection persists, the greater the resulting periradicular bone destruction.

Etiology

Vertical root fractures may arise from different factors which are either natural or iatrogenic. The etiology of VRFs is multifactorial, due to accumulation of predisposing factors i.e the repeated functional or parafunctional occlusal loads eventually leading to development of a VRF (over months or years).

Iatrogenic factors include: the excessive forces during root canal instrumentation, excessive tooth structure removal, or excessive obturation pressure.

Natural Predisposing Factors

A) Shape of Root Cross Section

One of the common anatomic features shared by teeth that typically develop VRFs is an oval cross section of the root, with buccolingual diameter being larger than the mesiodistal diameter. These teeth include the maxillary and mandibular premolars, the mesial roots of the mandibular molars, and the mandibular incisors. The fracture in these teeth typically starts in the buccolingual plane, specifically at the highest convexity of the oval root. This conclusion derived from large case series, is also supported by finite element analysis. Such analysis clearly demonstrated strain concentration on the inner side of the remaining dentin wall at the highest convexity point (i.e., the buccal and lingual sides of the oval roots).

B) Occlusal Factors

Excessive occlusal loads specifically in the case of mandibular second molars or load concentration as in cases of occlusal prematurities in maxillary premolars may, over time, lead to VRFs.

C) Preexisting Microcracks

Preexisting microcracks may be present in the radicular dentin, resulting from repeated forces of mastication or occlusal parafunction.

Iatrogenic Predisposing Factors

A) Root Canal Treatment

The most common dental procedure contributing to VRF is endodontic treatment. VRFs usually do not occur during the obturation of the root canal, but rather after the procedure has been completed.

Teeth were once thought to be more susceptible to fracturing after endodontic treatment because of a decrease in hydration. However, later studies found no difference in the properties of dentin, as a material, after endodontic procedures. Although the physical characteristics of the dentin, as a material, may not be compromised by endodontic treatment, the radicular dentin, as a structure, may be compromised by the combined effect of the endodontic treatment and the restoration of endodontically treated teeth. This may be the reason for the often-reported association of VRF with endodontically treated teeth.

B) Excessive Root Canal Preparation

To reduce the risk of VRFs, less invasive methods may be considered, such as minimally invasive endodontic instrumentation.

C) Microcracks Caused by Rotary Instrumentation

Shemesh and colleagues observed that root canal preparation using nickel-titanium rotary and reciprocating files often result in microcracks in the remaining radicular dentin. The researchers reported that rotary files induce strain on the dentin, as measured in the surface layers of the root dentin, which likely exceeds the elasticity of the dentin, causing subsequent microcracks. Whereas both hand instrumentation with files and the self-adjusting file did not cause such cracks.

D) Uneven Thickness of Remaining Dentin

Occurs due to:

1. The instrumentation of root canals particularly when curved canals are straightened.
2. Upon excessive instrumentation in the danger zone.

   (N.B: The anatomic groove that is often found on the palatal side of the buccal root of maxillary bifurcated premolars is another example of such a hidden danger zone).
3. Lingual access, (commonly used in incisors) may also result in a thinner buccal wall in the apical area as compared with the lingual wall.

The use of flexible nickel-titanium files and minimally invasive instrumentation with instruments such as the self-adjusting file may reduce such risks.

E) Methods of Obturation

Certain obturation techniques, such as lateral compaction, involve the application of internal pressure with a spreader, which may cause strains and subsequent propagation of microcracks into fractures across the full dentin thickness.

Other obturation methods which create less pressure, as thermoplasticized gutta-percha, may reduce the risk of VRFs.

F) Type of Spreader Used

The use of rigid and thick stainless-steel hand spreader may lead to increased strain in the radicular dentin resulting in an increased incidence of root fracture. The use of flexible finger spreaders, which have smaller diameter, may greatly reduce such risks. The nickel-titanium spreaders allow reduction in the strain induced in the radicular dentin during obturation.

G) Post Design

Post selection, design, and seating have a significant effect on the strain distribution in the root. Excessively long or thick posts are considered a predisposing factor for VRFs. The use of posts carries an inherent risk of root fracture, particularly if excessive sound dentin is removed during preparation. Posts should only be used when essential for core retention and should be avoided whenever a sufficient coronal tooth structure is available for the secure retention of the crown.

H) Crown Design

When considering endodontically treated teeth, crowns with a ferrule margin (i.e., supported by a sound tooth structure all around and beyond the gingival margins of the core) provide better strain distribution than those supported by the post and core alone.

TREATMENT PLANNING

Prevention is the key of management vertical root fractures. There are many predisposing factors of these fractures, all of which should be minimized as much as clinically possible. Comprehensive clinical, radiographic, and periodontal examination are imperative when evaluating any tooth that is planned for endodontic treatment or retreatment. A flexible periodontal probe is mandatory in such examinations. When a VRF is determined to be present, extraction of the affected tooth or root is recommended as soon as possible. Any delay may increase the potential for additional periradicular bone loss and possibly compromise the placement of an endosseous implant. Therefore, the measures that may allow the dentist to make the diagnosis at early stages are important.

SUMMARY

Developing accurate and early diagnosis, prognosis, assessment and treatment plan for teeth with suspected cracks and fractures is essential. In addition, endodontic and restorative procedures should focus on minimizing any offending and predisposing factors that may perpetuate cracks and fractures.

CHAPTER REVIEW QUESTIONS

1. How to differentiate between deep periodontal pocket and VRF pocket?
2. State the etiological factors predisposing to VRF.

REFERENCES

- Cohen's pathways of the pulp, Eleventh edition, 2016
- Lustig JP, Tamse A, Fuss Z. Pattern of bone resorption in vertically fractured endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90: 224–227.
- Hassan B, Metska ME, Ozok AR, Van Der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endod 2009;35: 719–722.
- Da Silveira PF, Vizzotto MB, Liedke GS. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography; an in vitro analysis. Dent Traumatol 2013;1: 41–46.
- Patel S, Brady E, Wilson R. The detection of vertical root fractures in root-filled teeth with periapical radiographs and CBCT scans. Int Endod J 2013;46: 1140–1152.
- Takeshita WM, Lwaki LV, Da Silva MC, Sabio S, Albino PF. Comparison of periapical radiography with cone beam computed tomography in the diagnosis of vertical root fractures in teeth with metallic post. J Conserv Dent 2014;17: 225–229.
- Neves FS, Freitas DQ, Campos PS. Evaluation of cone-beam computed tomography in the diagnosis of vertical root fractures: the influence of imaging modes and root canal materials. J Endod 2014;40:1530–1536.
- European Society of Endodontology. European Society of Endodontology position statement: the use of CBCT in endodontics. Int Endod J 2014;47: 502–504.
- American Association of Endodontists; American Academy of Oral and Maxillofacial Radiology joint position statement; use of cone beam computed tomography in endodontics. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2015;120: 508–512

20 Endodontic Surgery

Mohamed Abdel Azim

Intended Learning objectives

After reading this chapter, the student should be able to

1. Discuss the role of endodontic surgery as compared with non-surgical root canal therapy.
2. Define the terms incision and drainage, apical curettage, root-end resection, root amputation, hemisection, bicuspidization, and single tooth implant.
3. Illustrate the indications for the procedures incision and drainage, apical curettage, root-end resection, root-end preparation and filling, root amputation, hemisection, bicuspidization, and single tooth implant.
4. Outline in brief the procedures involved in periradicular surgery, including those for incision and reflection, acess to the apex, apical curettage, root-end resection, root-end preparation and filling, flap replacement and suturing.
5. List the commonly used root-end filling materials.
6. Write out the postsurgical instructions to be given to patients.
7. Report briefly endodontic microsurgery.

Master degree student should be able to:

1. Modify treatment plan according to various medical and dental findings for endodontic surgery.
2. Analyze the step by step procedures involved in periapical (endodontic) surgery.
3. Evaluate the outcome of endodontic surgery.

Ph.D student should be able to:

4. Point out frequency and distribution of radiolucent jaw lesions.
5. Relate surgical treatment plan according to diagnosis which is based on clinical and radiographic findings.
6. Realize the medical and dental situations in which endodontic surgery is contraindicated.
7. Correlate prevalence of periapical radiolucency to case selection for apical surgery.
8. Propose the treatment plan in mandibular and maxillary teeth according to anatomic considerations.
9. Comment on complex surgical cases and their proper treatment plan.
10. Describe the design of mucoperiosteal flaps according to the different surgical procedures.
11. Evaluate the healing of soft and hard tissue wound.

Chapter Outline

Definition:

- Endodontic surgery involves all surgical procedures performed to remove causative agents of periradicular pathosis and to restore the periodontium to a state of biologic and functional health.

Historical review:

- The first recorded surgical procedures was incision and drainage of acute periapical abscess, performed over 1500 years ago.
- To be proud that one of the earliest pioneers in that field is **Abulcasis (AbulKasim Al-Zahrawi, 936-1013) Fig. (1)** to whom the first intentional re-plantation was recorded.

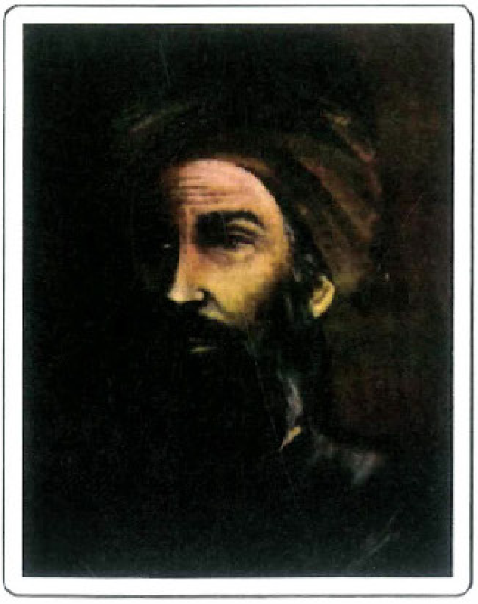


Fig. 1. Abulcasis(AbulKasimAl-Zahrawi, 936-1013)

- However some data back to ancient pharaohs pointing that surgical trephination in the mandible can be traced **Fig. (2)**.
- Few years ago endodontic surgery procedures were considered as last resort procedures.
- Recently, marked advances in technology as well as instruments and materials had widened the scope of surgical endodontic to increase the clinician capabilities and to increase and improve the prognosis of many cases once thought to be hopeless.

Fig. 2. Cortical trephination performed in mandible from Pharaonic era

Indications:

Etiology :

- Presence of bacteria and other microbial irritants.
- Enterococcus faecalis is the most commonly isolated bacteria from failed root canal treated teeth.
- Fungi and viruses can be considered as possible cause of failure.
- If bacteria and all other microbial irritants remain completely entombed within the confines of the root canal system, healing should occur; failure takes place when the irritants find a way to the periapical tissues.
- Established extravascular colonies could be considered as reason of failure. If microorganisms arrange in an extravascular biofilm which could be resistant to host defense mechanism and anti microbial agents.
- Over-extended filling material containing toxic materials such as formaldehyde.
- Presence of periradicular cholesterol may interfere with healing after non-surgical treatment.
- Presence of vertical root fracture the use of CBCT is of great help to aid in diagnosing such conditions.

- Systemic condition of patient as it might lead to delayed healing in patients especially with uncontrolled diabetes and immunosuppressive drugs.

- Previously, periradicular surgery was considered the treatment of choice when non surgical treatment failed or if not feasible such as in case of valuable prosthetic restoration.

- In the middle of last century Grossman (one of the famous endodontic pioneers) listed some of indications for endodontic surgery among which was teeth with large periapical radiolucency or over filled root canals, or teeth with open apicies or over instrumentation. However most of these indications are no longer valid, recently, the emphasis on retreatment of failures together with the advances in technology (microscope) and improvements in instruments and materials have led to increase success rate of retreatment cases.

- Although most recently some text books have listed the indications to be as follow **Fig. (3)**:

    1. Failure of non surgical retreatment.
    2. Failure of non surgical treatment and retreatment is not practical.
    3. Need for biopsy.

- However, the indications will be grouped as follow:

    1. Need for surgical drainage:
        a. Soft tissue (I&D).
        b. Hard tissue (trephination).
    2. Failed non surgical treatment:
        a. Rendered twice.
        b. Irretrievable root canal filling/ post.
    3. Calcific metamorphosis of pulp spaces (solid tooth).
    4. Procedural errors and non surgical retreatment or correction failed:
        a. Instruments separation.
        b. Ledging.
        c. Root perforation.
        d. Symptomatic overfilling.
    5. Anatomic variations:
        a. Root dilacerations.
        b. Apical root fenestration.
    6. Need for biopsy.
    7. Corrective surgery:
        a. Root resorption.
        b. Root caries.
        c. Root resection (amputation).
        d. Hemi section.
        e. Bisection (bicuspidization).
    8. Intentional replantation.
    9. Implant surgery:
        a. Endodontic implant.
        b. Osseointegrated implant.

Fig 3. Radiographs showing some of the conditions that require surgical intervention

Contraindications:

- Few absolute contraindications to endodontic surgery exist.
- Most contraindications are relative and usually limited to:

1. Anatomic considerations:

   The major anatomical landmark of importance to endodontic surgery include: Nasal floor, maxillary sinus, mandibular canal and it's neurovascular bundle and mental foramen.

2. Patient medical condition:

   It is imperative that thorough medical history should be taken since some medical conditions might necessitate either preoperative, operative, or post operative managements, according to each condition.

3. Dentist skill and experience:

   It goes without saying that any dental treatment rendered must be in the patient's best interest and at the highest quality of care.

Classification of surgical procedures:

1. Surgical drainage:
   a. Incision and drainage through soft tissue (I&D).
   b. Cortical trephination through hard tissue.
2. Periradicular surgery:
   a. Curetage.
   b. Root end resection (apicoectomy).
   c. Root end preparation and filling (retrograde).
3. Corrective Surgery:
   a. Perforation repair (mechanical/resorption).
   b. Periodontal management
      i. Root resection (amputation).
      ii. Tooth resection (hemisection/bicuspidization).
4. Replacement surgery (intentional replantation).
5. Implant surgery.
   a. Endodontic implant.
   b. Osseointegrated implant.

Anatomic considerations:

1. Inferior alveolar canal and mental foramen
2. Maxillary sinus
3. Nasopalatine neurovascular bundle

Cone beam computed tomography CBCT

Radiographic examination is an essential component in all aspects of endodontic treatment. The CBCT solves and helps to a great extent in diagnosis and treatment planning for periradicular surgery since it provides the third dimension which was overlooked through the regular 2D radiographs.

The main advantages of CBCT:

- Three dimensions
- Increased accuracy
- Higher resolution
- Significant reduction of the scan time
- Less radiation dose
- Reduced cost
- Highly sophisticated software which allows reconstruction of the collected huge volume of data.
- High accuracy of measurements in all dimensions
- Ability to view thin sagittal, coronal and axial slices eliminates the problem of superimposition.
- Early detection of any change in apical bone density
- Useful tool for differentiation of apical cyst or granuloma
- Plays an important role in microsurgery
- 3d visualization of root morphology
- Detection of location and extent of invasive external root resorption

Incision and Drainage (I & D)

Fluctuant soft-tissue swelling occurs when periradicular inflammatory exudate exits through the medullary bone and the cortical plate.

When this occurs, an incision should be made through the focal point of the localized swelling to relieve pressure, eliminate exudate and toxins, and stimulate healing. If the swelling is intraoral and localized, the infection may be managed by surgical drainage alone. However, if the swelling is diffuse or has spread into extra oral muscles of fascial tissues or spaces, surgical drainage should be supplemented with appropriate systemic antibiotic therapy **Fig. (4)**.

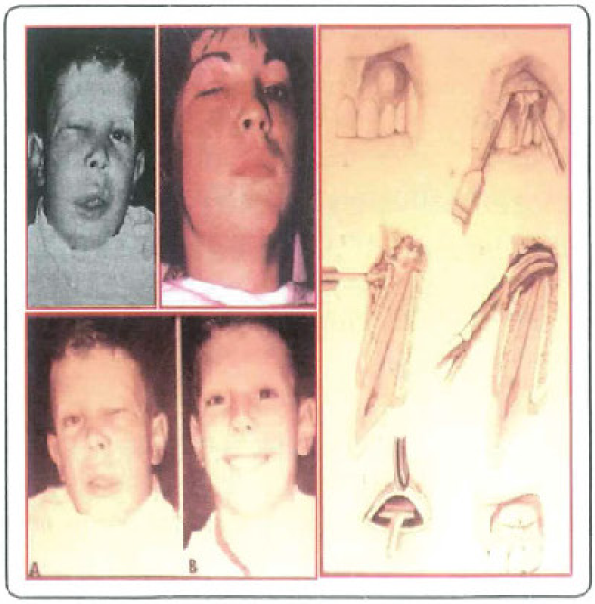


Fig. 4. Photographs showing cases with diffuse facial swellings.

The correct timing for I&D is important. Caution should always be exercised with hard, diffuse and indurated swellings. Especially when accompanied by a fever. Such an infection can extend into fascial planes and anatomic spaces and become life threatening.

Local anesthesia; whenever possible, nerve block injection is the preferable method for ob taining local anesthesia. In some cases, block injections must be supplemented with local infiltration to obtain adequate local anesthesia.

When local infiltration is used, the oral mucosa in the area to be injected should be dried with 2x2 gauze and a topical anesthetic is placed. Local anesthetic should be deposited peripheral to the swollen mucoperiosteal tissues. Injection directly into the swollen tissues should be avoided because it is painful, may cause spread of infection, and does not produce effective anesthesia.

The use of nitrous oxide analgesia may be useful in reducing patient anxiety and lowering the pain threshold.

The incision should be horizontal and placed at the dependent base of the fluctuant area. This will allow the greatest release (flow) of exudate. The incision should be made using a pointed scalpel blade such as a No. 11 or No. 12.

Probing with a curette or hemostat into the incisional wound to release exudate entrapped in tissue compartments.

Placement of a drain; The use of drains following an I&D procedure is controversial. If initial drainage is limited, placement of a drain may be indicated. The drain may be made of either iodoform gauze or rubber dam material cut in an "H" or "Christmas tree" shape. It may be sutured in place for added retention and should be removed after 2 to 3 days.

Cortical trephination

This is a limited-use procedure. Patients who presented with moderate to severe pain but with no intraoral or extraoral swelling may require drainage of periradicular exudate to alleviate the acute symptoms.

The treatment of choice for those patients is drainage through the root canal system (apical trephination) **Fig. (5)**.

Apical trephination involves penetration of the apical foramen with a small endodontic file and enlarging the apical opening to a size No. 20 or No. 25 file to allow drainage from the periradicular lesion into the canal space. The decision about whether to perform apical

or cortical trephination is based primarily on clinical judgement regarding the urgency of obtaining drainage.

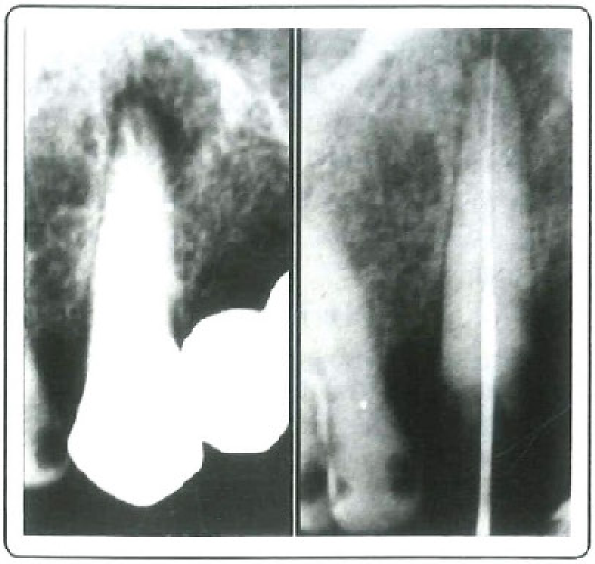


Fig. 4. Apical trephination

Cortical trephination involves making an incision through mucoperiosteal tissues or raising a flap and perforating through the cortical plate with a rotary instrument.

The objective is to create a pathway through the cancellous bone to the vicinity of the involved periradicular tissues.

The site most often recommended is at or near the root apex. Using either a No. 6 or No. 8 round bur in a high-speed handpiece to penetrate the cortical plate. A reamer or K-type file is then passed through the cancellous bone into the vicinity of the periradicular tissues.

Treatment planning for periradicular surgery

- The indications for and the application of periradicular endodontic surgery has undergone dramatic changes in the last two decades.
- The most important principle of endodontic diagnosis and treatment planning is that the primary modality for endodontic treatment failure should be non surgical endodontic retreatment whenever possible.
- The practitioner and staff be thoroughly trained, all necessary instruments, equipment, and supplies must be readily available in the treatment room.
- Good patient communication is essential for thorough surgical preparation, it is important that the patient understands the reason surgery is needed as well as other treatment options available. The patient must be informed of the prognosis, risks, benefits and the short term effects of the surgery such as pain, swelling, discoloration, and infection. Signed consent forms are essential.
- A presurgical mouth rinse will improve the surgical environment by decreasing the tissue surface bacterial contamination and thereby reducing the inoculation.
- Chlorhexidine gluconate has been shown to decrease salivary bacterial counts by 80% to 90% with a return to normal within 48 hours.
- Oral rinses should be started the day prior to surgery, immediately before surgery and continued for 4 to 5 days following surgery.

Concepts of periradicular surgical procedures

1. Need for profound local anesthesia and hemostasis.
2. Management of soft tissues.
3. Management of hard tissues.
4. Access to root structure.
5. Periradicular curettage.
6. Root end resection.
7. Root end preparation.
8. Root end filling.
9. Soft tissue repositioning and suturing.
10. Post surgical care.

Anesthesia and hemostasis:

The injection of a local anesthetic agent that contains a vasoconstrictor has two equally important objectives:

o To obtain profound and prolonged anesthesia.

o To provide good hemostasis both during and after the surgical procedure.

- The selection of an appropriate anesthetic agent should always be based on the medical status of the patient.
- The two major groups of local anesthetic agents are the esters and amides.
- The difference between them is in the manner by which they are metabolized and the potential for allergic reactions.
- Esters have a much higher allergic potential than amides.
- The amide group of local anesthetics, which include lidocaine, mepivicane, prilocaine, bupivicane, etidocaine, and articaine, undergo a complex metabolic breakdown in the liver.
- Patients with a known liver dysfunction should be administered amide local anesthetic agents with caution
- The high clinical success rate in producing profound and prolonged local anesthesia along with its low potential for allergic reactions make lidocaine (Xylocaine) the anesthetic agent of choice for periradicular surgery.
- It was reported that mandibular infiltration anaethesia with articane can provide profound local anaethsia needed to perform root canal treatment.
- The choice of vasoconstrictor in the local anesthetic will have an effect on both the duration of anesthesia and the quality of hemorrhage control at the surgical site.
- Epinephrine is the most effective and most widely used vasoconstrictor agent in the dental anesthetics, the other vasopressors available are less effective.
- Hemostasis unlike anesthesia, however, cannot be achieved by injecting into distant sites. Larger vascular channels are not affected by the injected vasopressor, only the small vessels of the microvasculature.
- An inferior nerve block injection effectively blocks pain transmission from the surgical site; however, the vasopressor injected has no effect on the inferior alveolar artery and normal blood flow continues to the peripheral surgical site. Therefore, additional injections must be administered in the soft tissue in the immediate area of the surgery.
- Vasopressor agents used in dentistry are direct acting, sympathomimetic amines that exert their action by stimulating special receptors on the smooth muscle cells in the microcirculation of various tissues. These agents include epinephrine (adrenalin), levonordefrin and norepinephrine (noradrenaline).
- There are two types of adrenergic receptors in tissues, alpha and beta, that respond differently when stimulated. However, depending on the specific tissue, one will usually predominate.
- The action of vasopressor drug on the microvasculature is dependent upon:
- The predominate receptor type.
- The receptor selectivity of the vasopressor drug.
- Alpha receptors predominate in the oral mucosa and gingival tissues while beta receptors predominate in skeletal muscles. Epinephrine receptor selectivity is approximately equal for alpha and beta receptors.
- Stimulation of the alpha adrenergic receptors will result in contraction of the smooth muscle cells in the microvasculature with a subsequent reduction of blood flow through the vascular bed.

- Stimulation of the beta-adrenergic receptors will result in a relaxation of the smooth muscle cells in the microvasculature with a subsequent increased blood flow through the vascular bed.
- As epinephrine selectivity is equal for alpha and beta receptors, and beta receptors predominate in the skeletal muscle, it is important not to inject epinephrine in skeletal muscles in the area of endodontic surgery or a vasodilation with increased blood flow will result.
- **Reactive Hyperemia** (the **rebound phenomenon).** It is important that the endodontic surgeon be aware of the delayed beta adrenergic effect that follows the hemostasis produced by the injection of vasopressor amines. The rebound occurs from an alpha (vasoconstriction) to a beta (vasodilation) response and is termed reactive hyperemia or the rebound phenomenon. This rebound phenomenon is not the result of beta receptor activity but results from localized tissue hypoxia and acidosis caused by the prolonged vasoconstriction.

Soft Tissue Management and Flap Design:

Principles of Flap incisions:

1. Avoid horizontal and severely angled vertical incisions, to avoid cutting a large amount of gingival blood vessels that run parallel to the long axis of the teeth. Horizontal and severely angled incisions, such as used in semilunar flaps and in broad-based rectangular flaps, shrink excessively during surgery as a result of contraction of the cut collagen fibers that run perpendicular to line of incision. As a result of this shrinkage it is difficult to return the flap edges to its original position without excessive tension, which results in tearing of the sutures and subsequent scar formation from healing by secondary intention.
2. Avoid incisions over radicular eminences, such as, canine, maxillary first premolar, and mesio buccal root of first molar. Which often fenestrate through the cortical bone or covered by very thin bone, which may lead to soft tissue fenestration if incisions are made over them.
3. Incisions should be placed and flaps repositioned over solid bone. Incisions should never be placed over areas of periodontal bone loss or periradicular lesions.
4. Avoid incisions across major muscles attachment (frena) hence it can make repositioning of the flap and subsequent healing much more difficult. Healing by secondary intention with scar tissue formation often results.
5. Tissue retractor should rest over solid bone.
6. Extent of the horizontal incision should be adequate to provide visual and operative access with minimal soft tissue trauma. It should extend at least one to two teeth, lateral to the tooth to be treated.
7. The junction of the horizontal sulcular and vertical incisions should either include or exclude the involved interdental papilla **Fig. (6)**.

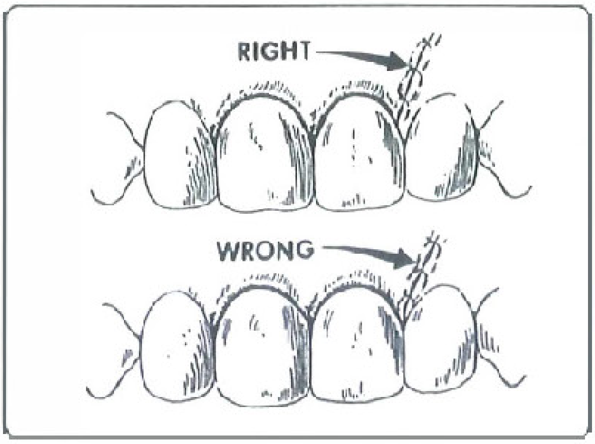


Fig. 6. The vertical incision should either include or exclude the involved interdental papilla

8. The flap should include the entire mucoperiosteum (full thickness). Full thickness flap result in less surgical trauma to the soft tissues and better surgical hemostasis than split thickness flap.

Classification of surgical flaps:

They are classified into full mucoperiosteal flaps and limited mucoperiosteal flap. The difference between them is in the location of the horizontal incision. The full thickness mucoperiosteal flaps involve intrasulcular horizontal incision with reflection of the marginal gingival and interdental papillary tissues. While in limited mucoperiosteal flaps the horizontal incision is submarginal (subsulcular) and the flap does not include the marginal or interdental tissues.

Surgical flaps:

1. ***Full mucoperiosteal flaps***
   a. Triangular (one vertical releasing incision).
   b. Rectangular (two vertical releasing incisions).
   c. Trapezoidal (broad-based rectangular).
   d. Horizontal (no vertical releasing incision).
   e. Papilla-base flap.

2. ***Limited mucoperiosteal flaps***
   a. Submarginal curved (Semilunar).
   b. Submarginal scalloped rectangular *(Luebke-Ochsenbein).*

1. ***Full Mucoperiosteal Flaps:***
   a. Triangular flap:

   The triangular flap is formed by a horizontal, intrasulcular incision, and one vertical releasing incision **Fig. (7)**.

- Advantages:
  - o Good wound healing.
  - o Minimal disruption of the vascular supply.
  - o Ease of flap re-approximation.
  - o Minimal number of sutures required.
- Major disadvantage is the limited surgical access.

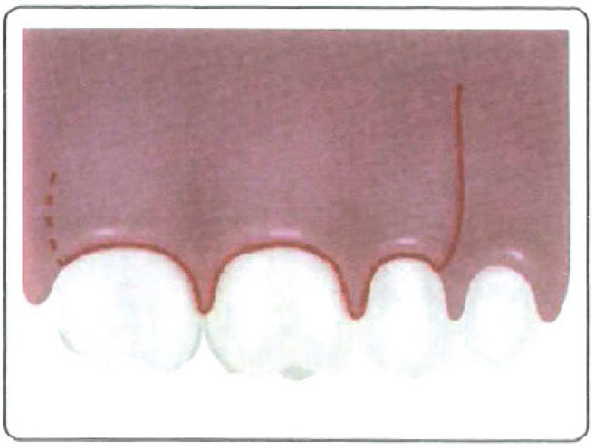


Fig. 7. Full mucoperiosteal triangular flap with one vertical incision and a horizontal intrasulcular incision a distal vertical relaxing incision (dotted line) is often used to relieve tension on soft tissues during flap reflection and increases visibility for a maxillary first molar

In posterior surgery, both maxillary and mandibular, the vertical releasing incision is placed at the mesial extent of the horizontal incision, which gives the surgeon the maximum visual and operative access with minimum soft tissue trauma.

For anterior surgery, the vertical releasing incision should be placed at the extent of the horizontal incision closest to the surgeon and is therefore dependent on the surgeon's position to the right or left of the patient.

b. Rectangular flap:

The rectangular flap is formed by an intrasulcular, horizontal incision and two vertical releasing incisions **Fig. (8)**.

1. Advantages:

1. Increased surgical access.
2. This flap design is especially useful for mandibular anterior teeth, when multiple teethare involved in the surgery, and for teeth with long roots such as maxillary canines.

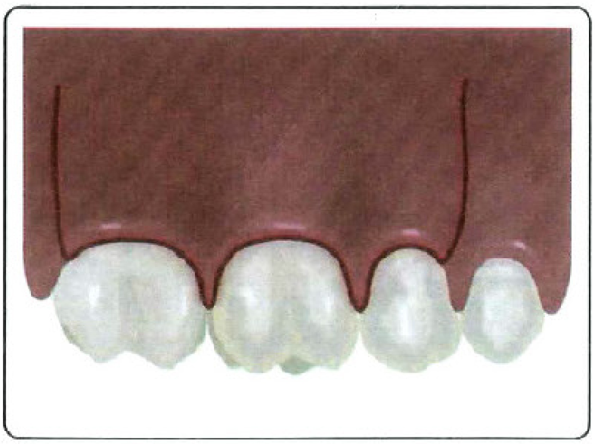


Fig. 8. Full mucoperiosteal rectangular flap with two vertical releasing incisions and a horizontal intrasulcular incision. Rectangular flaps are frequently used in the mandibular anterior region or when multiple teeth require endodontic surgery.

2. *Disadvantages:*

   1. Difficulty in re-approximation.
   2. Postsurgical stabilization is also more difficult with this design than the triangular flap.

c. Trapezoidal flap:

The trapezoidal flap is similar to the rectangular flap with the exception that the two vertical releasing incisions intersect the horizontal, intrasulcular incisions at an obtuse angle.

The desirability of this flap design is built on the assumption that this will provide a better blood supply to the flapped tissues. While this concept is valid in other tissues, such as the skin, its application is unfounded to periradicular surgery.

d. Horizontal flap:

Horizontal, intrasulcular incision with no vertical releasing incisions.

This flap design has very limited application in periradicular surgery due to the limited surgical access it provides.

It's major applications in endodontic surgery are limited to repair of cervical defects (root perforations, resorption, caries, etc) and hemisections and root amputations.

e. Papilla-base flap:

The papilla-base flap is designed to prevent recession of the papilla following endodontic surgery as it essentially excludes the papillae **Fig. (9)**.

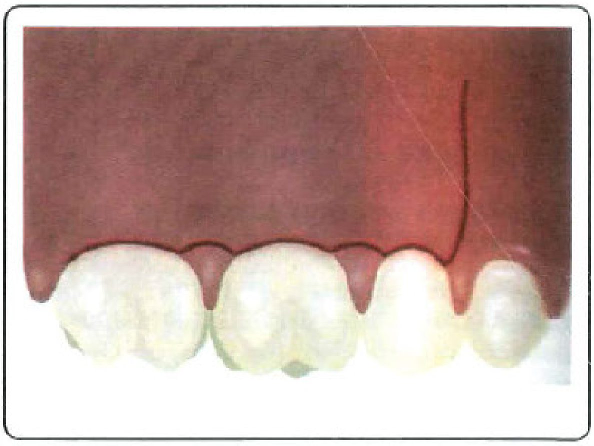


Fig. 9 Papilla-based flap consists of at least one vertical incision connected by the papilla-based incision and intrasulcular incision in the cervical area of the teeth. This flap is designed to preserve the papilla and prevent recession.

It is highly indicated when valuable cosmotic restorations are present in the surgical area.

Although this flap design is more challenging to master, if properly executed, it can produce excellent results.

2. *Limited Mucoperiosteal Flaps:*

i. Submarginal curved (Semilunar) flap:

The submarginal curved or semilunar flap is formed by a curved incision in the alveolar mucosa and the attached gingiva.

There are no advantages to this design, and

its disadvantages are many including poor surgical access and poor wound healing which result in scarring.

This flap design is not recommended for periradicular surgery.

ii. Submarginal scalloped rectangular flap *(Luebke-Ochsenbein)*:

The submarginal scalloped rectangular flap is a modification of the rectangular flap discussed previously in that the horizontal incision is not placed in the gingival sulcus but in the attached gingiva **Fig. (10)**.

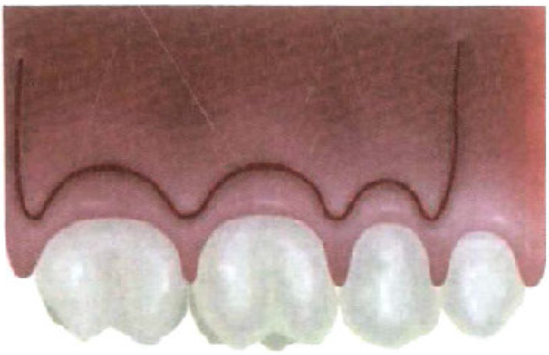


Fig. 10. Limited mucoperiostal Luebke-Ochsenbein flap with two vertical incisions connected by a scalloped submarginal horizontal incision in the attached gingiva. This design is essentially limited to the maxilla with a sufficient amount of attached gingiva.

The horizontal incision is scalloped and follows the contour of the marginal gingiva above the free gingival groove.

The major advantage is that it does not involve the marginal or interdental gingiva and the crestal bone is not exposed.

The primary disadvantages is that the vertically oriented blood vessels and collagen fibers are severed, which results in more bleeding and a greater potential for flap shrinkage, delayed healing, and scar formation.

- Periradicular surgery from a palatal approach is more difficult due to the clinician's limited visual and operative access to this area. The only flap designs indicated for palatal approach surgery are the horizontal (envelope) and the triangular, with the latter being preferred. The palatal surgical approach should be limited to the posterior teeth.

Hard tissue management and curettage:

Two key factors should and must be kept in mind during bony access which are:

- Healthy hard tissue must be preserved as much as possible
- Heat generation during the procedure: heat in the osseous tissues up to 47-50°C for 1 minute greatly reduces bone formation and leads to cellular damage.

Bone removal is best accomplished using carbide round bur in brush stroke motion.

- The most difficult and challenging situation for the endodontic surgeon is when several millimeters of cortical and cancellous bone must be removed to gain access to the root, especially when no periradicular radiolucent lesion is present.
- A number of factors should be considered to determine the location of the bony window in this clinical situation.
- The angle of the crown of the tooth to the root should be assessed.
- Measurement of the entire tooth length can be obtained from a well-angled radiograph and transferred to the surgical site by the use of a measured sterile file or ruler.
- A radiopaque marker, such as a small piece of lead foil from a radiographic film packet or a small piece of guttapercha, can be placed on the bony defect and a direct image exposed. The radiopaque object will provide guidance for the position of the root apex.

- The root surface can be distinguished from the surrounding osseous tissue in four ways:
  - o Root structure generally has a yellowish color.
  - o Roots do not bleed when probed.
  - o Root texture is smooth and hard as opposed to the granular and porous nature of bone.
  - o It is surrounded by the periodontal ligament.
- Under some clinical conditions, the root may be very difficult to distinguish from the surrounding osseous tissue.
- Some authors advocate the use of methylene blue dye to aid in the identification of the periodontal ligament. A small amount of the dye is painted on the area in question and left for 1 to 2 minutes. When the dye is washed off with saline, the periodontal ligament will be stained with the dye making it easier to identify the location of the root.
- The use of endodontic microscope had made this problem easier to handle.
- The use of a liquid coolant is indispensable in controlling temperature increase during bone removal.
- The Impact Air 45 degree high speed handpiece **Fig. (11)** offers the added advantage that the air is exhausted to the rear of the turbine rather than toward the bur and the surgical site which could result in:

Fig. 11. Air impact 45 handpiece

  - o Emphysema.
  - o Potential hazards of pressurized nonsterile air blown into open surgical sites.
- Once the root and the root apex have been indentified and the surgical window through the cortical and medullary bone has been properly established, any diseased tissue should be removed from the periradicular bony lesion.
- This removal of periradicular inflammatory tissue is best accomplished by using various sizes and shapes of sharp surgical bone curettes and angled periodontal curettes.
- Prior to the periradicular curettage, it is advisable to inject a local anesthetic solution containing a vasoconstrictor into the soft tissue mass. This will reduce the possibility of discomfort to the patient during the debridement process and will also serve as hemorrhage control at the surgical site.

Fig. 12. Photographs for case of apical curettage

- Curettage of the inflammatory soft tissue will be facilitated if the tissue mass can be removed in one piece **Fig. (12)**. Penetration of the soft tissue mass with a curette will result in increased hemorrhage, and shredding the tissue will result in more difficult removal. To accomplish removal of the entire tissue mass, the largest bone curette, consistent with the size of the lesion, is placed between

the soft tissue mass and the lateral wall of the bony crypt with the concave surface of the curette facing the bone. Pressure should be applied against the bone, and the lesion being scoped and removed in one piece.

Need for Hemostasis Fig. (13):

1. ***Mechanical:***
   a. Bone wax (non-resorbable).
   b. Calcium sulphate (resorbable).
2. ***Chemical:***
   a. Vasoconstrictor (epinephrine).
   b. Ferric sulphate.
3. ***Biological:***
   a. Thrombin.
   b. Gelatin (Gelfoam).
   c. Collagen (Collatape/Collacot).

Fig 13. Need for hemostasis

BONE WAX was introduced by Horsley in 1892, it is made of purified beeswax (88%) in addition to isopropyl palmitate (12%) as softening agent, its mode of action is purely mechanical. After compeletion of surgery it has to be removed completely since some persistant inflammation and delayed healing was reported. The availability of more biocompatible and resorbablehaemostatic agents made bonewax not recommended in periradicular surgery

CALCIUM SULPHATE (plaster of Paris) used in surgery over 100 years . It is biocompatible and resorbs completely in 2 to 4 weeks,if some traces left in place it does not cause increase in inflammation, it is inexpensive, and being porous material thus allowing fluid exchange within the bony cavity. Recently it gains popularity as barrier in guided tissue regeneration.

VASOCONSTRICTOR; such as epinephrine which is most effective and most often recommended. It is available in form of cotton pellets containing epinephrine in various concentrations (Epidri/ Racellete/ Radri). It is of great importance not to leave any cotton fibers at the surgical site as it might impair wound healing. It should be used with caution in patients with severe heart disease.

FERRIC SULPHATE; was first introduced in 1857 as (Monsel's solution). Its mode of action results from agglutination of blood proteins for its acidic pH. In contrast to vasoconstrictors ferric sulphate affects hemostasis through a chemical reaction rather than an alpha adrenergic effect. It is easy to apply, and hemostasis is achieved almost immediately,but it is cytotoxic and may cause tissue necrosis and tattooing of tissues.

THROMBIN; acts to initiate the extrinsic and intrinsic clotting pathways. It is not widely used in endodontic surgery. Its main disadvantages are difficult handeling and high coast.

GELATIN; (Gelfoam/ Spongostan) are water insoluble and resorbable. They are hard gelatin based sponges made of animal skin gelatin,and becomes soft in contact with blood. It works intrinsically by promoting disintegration of platelets causing subsequent release of thromboplastin which stimulates the formation of thrombin. Once gelatin contact blood it swells and forms soft gelatinous mass. Best used before closure of surgical site to guard against postsurgical bleeding from the "rebound phenomenon" or in extraction socket.

COLLAGEN; have been used extensively as surgical hemostatic agents. The mechanism of action is thought to be: 1) stimulation of platelet adhesion, aggregation and thromboplastin release 2) activation of factor V111 (Hageman factor) 3) mechanical action 4) release of serotonin. The collagen used is obtained from bovine sources, and supplied in sheets (Collatape) or sponge pads (Actifoam), both can achieve hemostasis in 2 to 5 minutes.

MICROFIBRILLAR collagen; it provides collagen framework for platlet adhesion and formation of plug that occlude the open vessels.

ROOT-END RESECTION

Two main principles affect the extent of root – end resection:

1. The cause of the disease must be removed
2. Adequate room for inspection and management of the root end.

ANGLE OF RESECTION

The recent technology concerning the magnification and illumination techniques have eliminated to a great extent the need to bevel the root end. Biologically the most appropriate angle of resection is to be perpendicular to the long axis of the tooth for 2 main reasons:

1. Perpendicular resection of the apical 3mm will include all the apical ramifications.
2. Perpendicular resection will expose less dentinal tubules than the beveled resection.

The cut surface should be as smooth as possible for better inspection of any possible cracks or defects. This is best obtained by a multipurpose bur followed by ultrafine diamond finishing bur.

When endodontic surgery is performed in the area around the root apex, root-end resection is almost always a component of the surgical procedure. It has been reported that resection of the apical 3 mm of the root apex will eliminate 98% of the apical ramifications and 93% of the lateral canals which could contain material that would contribute to the periradicular disease. Performing periradicular curettage without root-end resection is generally indicated when the surgical procedure is being performed solely to obtain the periradicular soft tissue lesion for biopsy purposes.

INDICATIONS

Root end resection is indicated for different reasons. Removal of the root apex will aid in elimination of anatomical variations, resorptive defects, ledges, perforation defects, canal obstructions, and separated instruments that may be present in this area of the root and to gain access for the removal of pathologic tissue that may be trapped along the lingual surface of the root. The indications can be classified into either biological or technical.

The most common biological factors were persistent symptoms and continued presence of a periradicular lesion. The most common technical factors were the presence of post and core restorations, crowned teeth without posts, irretrievable root canal obturating materials and procedural accidents.

Three important factors should be considered: The type of bur or laser energy used, level of root resection and how much root end should be resected, and the angle at which the root end should be beveled.

A) BUR/LASER SELECTION

Though various types of burs have been recommended for root-end resections, there is no evidence to support any advantage of one bur type over another with regard to tissue healing response.

The plain fissure bur, both at high and slow-speeds, produces the smoothest resected root

surface, and the plain fissure bur at slow-speed results in the least distortion of the gutta-percha.

Many investigators have studied or reported on the ex vivo and in vivo effects of the application of laser energy to perform root-end resections.

Various forms of laser have been used among which are:

Er: YAG, Ho:YAG, (CO_2) laser and Nd: YAG laser

The advantages of using laser can be listed as follow:

1. No smear layer or debris left on the resected root surfaces.
2. Improves hemostasis.
3. Improves visualization.
4. Sterilize contaminated root apex.
5. Reduction in permeability of cut root surface dentin.
6. Reduction of postoperative pain.
7. Reduced risk of contamination of the surgical site through the elimination of a need for aerosol-producing air turbine handpieces.
8. The absence of discomfort and vibrations.
9. Reduced risk of trauma to adjacent tissue.

Regardless of the technique used for root-end resection, the cut root surface must be carefully examined for possible cracks, anatomical variations, and the adequacy of the orthograde obturating material, which can be accurately assessed with the operating microscope.

B) EXTENT OF THE ROOT-END RESECTION

Conservation of root length should not compromise the goals of the surgical procedure.

There is no agreement on how much of the root end should be resected. The extent of root end resection will be related to number of variable factors that must be evaluated on an individual case-by-case basis.

The shape of the root and the number and location of canals within the root may dictate the amount of root resection.

The amount to be resected may also be affected by the location of perforation defects, ledges, separated instruments, and the apical extent of posts and orthograde obturating materials. The level of the crestal bone and the presence of periodontal defects will be major factors in determining how much root end can or should be resected.

C) ANGLE OF ROOT-END RESECTION

Historically, endodontic text books and other literature have recommended that the angle of root-end resections, when used in periradicular surgery, should be 30° to 45° from the long axis of the root facing toward the buccal or facial aspect of the root.

In the past, the bevel was placed strictly for the convenience of the surgeon, but with modern microsurgical instruments and use of the surgical operating microscope, this need is no longer justified.

Beveling of the root-end results in opening of more dentinal tubules on the resected root surface that may communicate with the root canal space and result in apical leakage,

Root-End Preparation

It is the most important step to establish proper apical seal. The goal is to create a cavity in the resected root that is sufficient for the placement of the root-end filling material. The ideal preparation is a class I cavity prepared along the long axis of the tooth to a depth of at least 3mm. traditionally, a micro-head hand-piece with rotating bur has been used for this purpose. However, new ultrasonic devices and tips are designed especially for this purpose, where root-end preparations are often performed using ultrasonics.

Advantages of ultrasonic preparations over the micro handpiece:

1. Minimal osteotomy to gain access to the resected root-end.
2. Ability to perform more conservative preparation that follows the long axis of the tooth.
3. Decrease risk of root-end perforation.
4. Ability to produce deeper cavity preparations.
5. Decrease the need for beveling of the root-end.
6. Less smear layer formation.

The major disadvantage is the possibility of root fractures and cracks as a result of ultrasonic vibration.

- Bur-Type preparation:
  - o Using round or inverted cone bur in miniature hand piece **Fig. (14)** or pediatric size contra angle head hand piece.

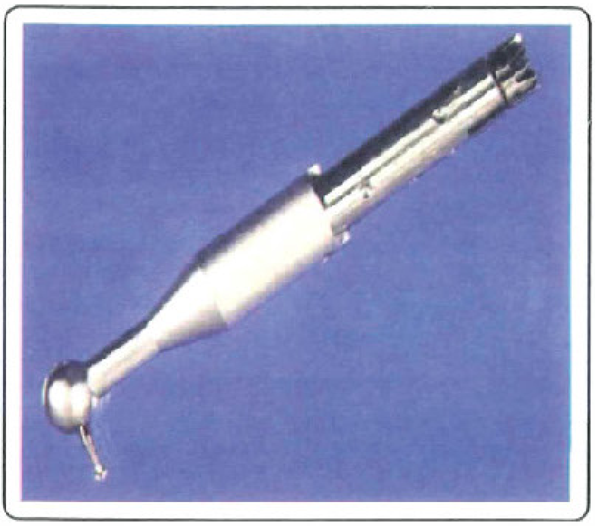


Fig. 14. Magnified picture for miniature hand piece

  - o Historically, there were different cavity designs done using burs either class **I, II** (slot preparation) or tunnel preparation **Fig. (15)**.

- The introduction of ultrasonics in root end preparation have led the bur type preparation to limited use in modern dentistry.

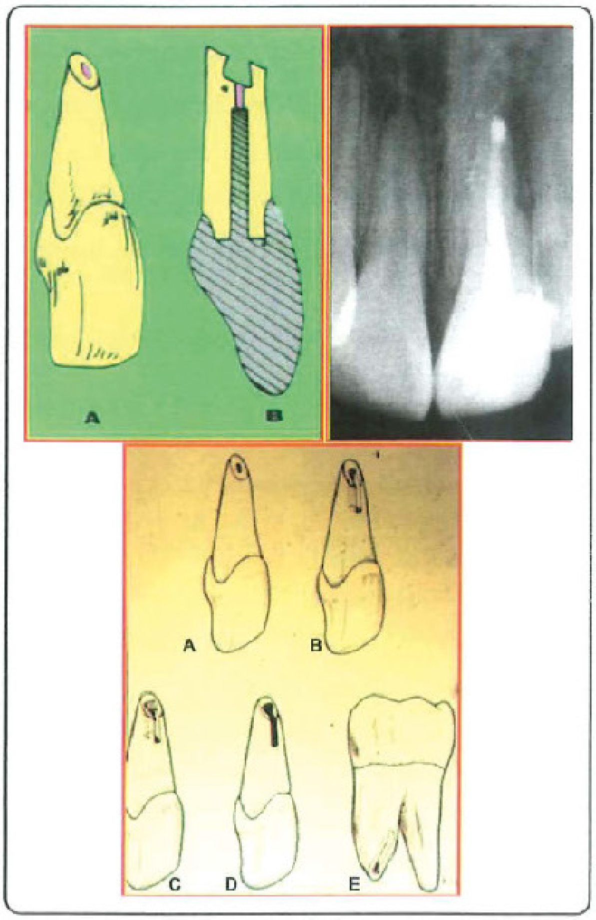


Fig. 15 Class I, II bur type preparation

Requirements for root-end preparation:

1. The apical 3mm of the root canal must be freshly cleaned and shaped.
2. The preparation must be parallel to and coincident with the anatomic outline of the pulp space.
3. Adequate retention form must be created.
4. All isthmus tissue, when present, must be removed.
5. Remaining dentin walls must not be weakened.

One of the major objectives of a root end preparation is that it should be placed parallel to

the long axis of the root. It is rare that sufficient access is present to allow a bur in a contra angle or straight handpiece to-be inserted down the long axis of a root.

One of the most significant advances in periradicular surgery was the introduction of ultrasonic micro-surgical tips for the root-end preparation with the following advantages:

1. Less need for root-end beveling.
2. The tip is able to stay centered in the root and follow the original root canal space.
3. Decreasing the possibility of lingual or lateral root perforations.
4. Conserving a greater thickness of the remaining root canal wall.
5. Smaller osteotomy is required to accommodate the ultrasonic tips.
6. Deeper root-end preparation.
7. Less dentinal tubules were exposed decreasing the chances of leakage around the root-end filling material.
8. Root-end cavity is much cleaner with ultra sonic tip preparations as compared to bur preparations.

Ultrasonic tips:

First developed by Dr. Gary Carr, either plain stainless steel or diamond coated tips. More recently introduced is the Kis microsurgical tips coated with zirconium nitride for faster dentin cutting with less ultrasonic energy, as one of the reported disadvantage of ultrasonic is the formation of cracks in the dentin surrounding the root-end preparation **Fig. (16)**

Root end surface treatment and conditioning:

Three solutions can be used for root surface treatment, namely:

1. Citric acid
2. Tetracycline

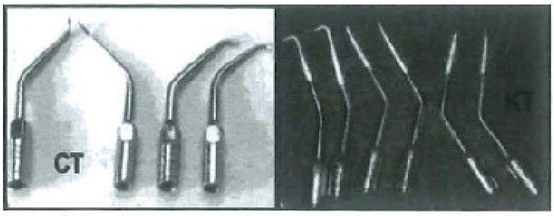


Fig. 15. CT st.st tips and KT (Kis tips) coated with zirconium nitride for faster cutting with low ultrasonic energy

3. EDTA

These solutions enhance the fibroblast attachment to root surface, based on periodontal studies. However, citric acid is the only one tested in animal studies for root end cavity surface treatment. Torbinejad (manufacturer of MTA) advised not to use EDTA, when MTA is used as the root end filling material as he claimed that it might interfere with the hard tissue producing the effect of MTA.

ROOT-END FILLING MATERIALS

Many materials have been used as root-end filling materials including: gutta percha, polycarboxylate cement, silver points, titanium screw, zinc phosphate cement, amalgam and gold foil. However, the most commonly used materials are:

1. Zinc oxide and eugenol cement
2. Intermediate restorative material (IRM)
3. Super EBA
4. Glass ionomer cement
5. Diaket
6. Composite resin
7. Mineral trioxide aggregate (MTA)
8. Bioceramics

The purpose of root-end filling is to establish a seal between the root canal space and the periradicular tissues. An ideal root-end filling material should be (1) able to prevent leakage

of bacteria and their byproducts into the periradicular tissues, (2) non-toxic, (3) non-carcinogenic, (4) biocompatible with the host tissues, (5) insoluble in tissue fluids, (6) dimensionally stable, (7) unaffected by moisture during setting, (8) easy to use, (9) radiopaque, (10) nonstaining, and (11) bioinductive (promote cementogenesis). Numerous materials have been suggested for use as root-end fillings including gutta-percha, amalgam, Cavit, intermediate restorative material (IRM), Super EBA, Diaket, glass ionomers, composite resins, carboxylate cements, zinc phosphate cements, zinc oxide eugenol cements, and mineral trioxide aggregate (MTA).

Based on a review of the currently available literature, there does not appear to be an "ideal" root-end filling material. MTA appears to be the currently-available material that most closely meets the requirements both physical and biological for a root-end filling material, especially due to its regenerative potential. Its primary disadvantage is its handling characteristics. Recently introduced is white MTA with less potential for staining. Care must be taken not to wash out the filling material by irrigation prior to closure of the soft tissue. The setting time of MTA is 2.5 to 3 hours.

Soft tissue management, suturing, and postoperative care

After final inspection of the root-end filling remove all visible excess filling material and any surgical packing, a radiograph should be taken to evaluate the placement of the root-end filling and to check for the presence of any root fragments or excess root-end filling material.

REPOSITIONING AND COMPRESSION

The elevated mucoperiosteal tissue should be gently replaced to its original position with the incision lines approximated as closely as possible.

SUTURING

The purpose of suturing is to approximate the incised tissues and stabilize the napped mucoperiosteum until reattachment occurs.

Sutures are available in many different materials, the most common being synthetic fibers [nylon, polyester, polyglactin (PC), and polyglycolic acid (PGA)], collagen, gut, and silk. Sutures are classified as absorbable or nonabsorbable, by size according to the manufacturer's minimum diameter, and by physical design as monofilament, multifilament, twisted, or braided.

SILK

Silk sutures are made of protein fibers (fibroin) bound together with biological glue (sericin), non-absorbable, multifilamentous, and braided. Due to the severe tissue reaction to silk, it is not the suture material of choice for endodontic surgery today.

GUT

Collagen is the basic component of plain gut suture material and is derived from sheep or bovine intestines, it is monofilament absorbable; up to 10 days. Chromic gut sutures consist of plain gut that has been treated with chromium trioxide which results in a delay of its absorption. Plain gut is more biocompatible with oral soft tissues than chromic gut.

COLLAGEN

Reconstituted collagen sutures are made from bovine tendon after it has been treated with cyanoacetic acid and then coagulated with acetone and dried.It has no advantage over gut for endodontic surgery, used almost exclusively in microsurgery.

PGA

Sutures made from fibers of polymerized glycolic acid are absorbable in mammalian tissue. The rate of absorption is about 16 to 20 days. PGA sutures consist of multifilamentous that are braided absorbable and manufactured as Dexon.

PG

In 1975, the development of a copolymer of lactic acid and glycolic acid called PG 910 (90 parts glycolic acid and 10 parts lactic acid), it is absorbable of braided multi-filamentous. Absorption rate is similar to that of PGA. They are commercially available as Vicryl.

NEEDLE SELECTION

Surgical needles are designed to carry the suture material through the tissues with minimal trauma. For that reason, a needle with a reverse cutting edge (the cutting edge is on the outside of the curve) is preferable.

SUTURING TECHNIQUES

1. Single interrupted suture.
2. Interrupted loop (interdental suture).
3. Vertical mattress suture.
4. Single sling suture.

POSTOPERATIVE CARE

1. Limit physical activity for the first 24 hours.
2. Have a good diet and drink plenty of liquids for the first few days after surgery.
3. Do not brush in the area of the incision for the first 3 days.
4. Do not lift up your lip or pull back your cheek to look where the surgery was done.
5. A little bleeding from where the surgery was done is normal.
6. Place an ice bag (cold) on your face where the surgery was done. You should leave it on for 20 minutes and take it off for 20 minutes. You should do this for 6 to 8 hours. The next day after surgery, you can put a soft, wet, hot towel on your face where the surgery was done. Do this as often as you can for the next 2 to 3 days.
7. Discomfort after the surgery is normal and pain killer is recommended.
8. Rinse your mouth with one tablespoon of the chlorhexidine mouthwash.
9. The stitches that were placed need to be taken out in a few days.
10. If you have any problems or if you have any questions, you should call the office.

CORRECTIVE SURGERY

Corrective surgery can be defined as the surgical procedure required to repair defects that occur in root or furcation areas as a result of mechanical or pathologic processes. These defects are located in areas of the root other than the apex.

Conditions requiring corrective surgery either due to procedural errors such as perforations or pathological as a result of caries, periodontal lesions, external resorption, and perforating internal resorption.

Corrective surgical procedures include periradicular surgery where access is gained through a flap procedure to repair the root and periodontal defects. Root amputation is also a possibility when a defect can only be corrected if an entire root of a multirooted tooth is removed and the remaining crown of the tooth is recontoured and retained. In mandibular molars a hemisection procedure may be required to remove the entire crown and root on the side of the tooth where the defect is present. An intentional replantation procedure is only a treatment option when all other nonsurgical and surgical procedures have already been attempted and failed or have been deemed impossible to perform. In these cases the tooth is extracted, the defect repaired, and the tooth repositioned into its original socket.

PERFORATION REPAIR

Perforations in the floor of the pulp chamber in multirooted teeth may occur during endodontic access preparation, post space preparation, or in conjunction with extensive caries or resorption lesions.

The initial attempt at repair should be from an internal, nonsurgical approach. Corrective surgery is reserved for those teeth where nonsurgical repair is not a treatment option or the attempted nonsurgical repair has failed. When surgery is necessary, a buccal mucoperiosteal flap is reflected, the furcation bony defect is curetted to remove any pathologic tissue, and the perforation site is repaired.

Treatment depends on two factors:

1. Whether the defect is perforating and communicating with pulp space or not.
2. The location of the defect.

If not perforating, buccal envelop gingival flap might be enough or raising a full mucoperiosteal flap and lesion is repaired with MTA, amalgam, glass ionomer or composite resin depending on whether lesion lies in cosmotic area or not.

If perforating, internal repair should be attempted first or surgical treatment is done.

The location of the defect: if at cervical or mid root surgical approach is indicated. If located apically root end resection and filling are indicated.

If located in an inaccessible area, the treatment would be either intentional replantation or extraction.

ROOT AMPUTATION Fig. (17)

Root amputation procedures may be indicated when a mutirooted tooth has one root that cannot be retained and the other roots have adequate periodontal support and the remaining crown structure can be restored. These procedures are most frequently encountered in maxillary molar involved with chronic periodontal disease specially mesiobuccal and distobuccal roots. Palatal root amputations are rarely performed because of the poor prognosis of retention of these teeth with just the two retained buccal roots. Root amputation is not the treatment of choice of a mandibular molar and only indicated in mandibular molars when the tooth is acting as an abutment for a well-fitting serviceable fixed bridge.

Fig. 17. Root amputation procedure of distobuccal root

There is a tendency in today's dental practice to extract these teeth and replace them with osseointegrated implants.

Contraindications for this procedure include:

1. Remaining roots do not have adequate periodontal osseous support.
2. Teeth with fused roots.
3. The remaining roots cannot be successfully treated endodontically.
4. The patient has poor home care and oral hygiene.

Nonsurgical root canal therapy should be completed on the roots to be retained before performing the amputation procedure. The root

to be amputated should be cleansed and shaped and filled with either amalgam or MTA. Once the restorative materials have set, the surgical procedure can be performed.

HEMISECTION Fig. (18)

When root removal is indicated in a mandibular molar because of a vertical root fracture, procedural errors or pathologic resorptive process, hemi-section is usually the treatment of choice. Due to the difficulties noted above in attempting to perform a root amputation procedure on mandibular molars, removal of one-half the tooth is a more predictable treatment procedure. This procedure is also falling out of favor as a treatment procedure today because the prognosis for success with osseointegrated implants is much better than that for hemisected teeth. As with a tooth amputation, nonsurgical endodontic therapy is completed first and then core material or a post and core restoration is placed into the coronal aspect of the root to be retained and pulp chamber.

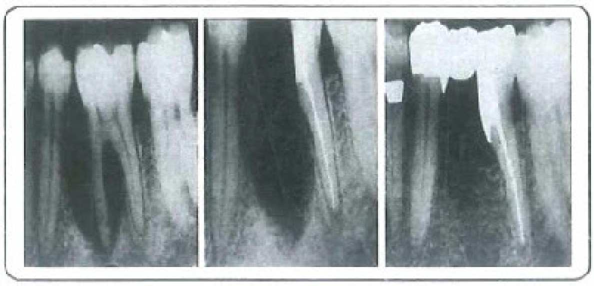


Fig. 18. Radiographs for hemisection case

BICUSPDIZATION Fig. (19)

It is the same procedure as hemisection but both roots will be retained. It is done when the defect lies in the bifurcation and both roots are able to be retained. The procedure was found to have a very poor long-term prognosis and is rarely recommended as a treatment option today.

PERIODONTAL REGENERATIVE PROCEDURES

Some situations are encountered requiring periodontal regenerative procedures in addition to the corrective root surgery. These regenerative procedures may include, placement of decalcified freeze-dried bone allograft or calcium sulfate materials and guided tissue procedures using either resorbable or nonresorbable membranes.

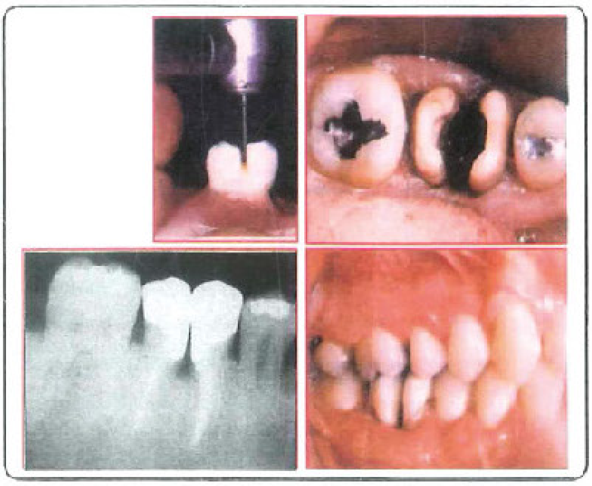


Fig 19. Photographs for bicuspdization case

INTENTIONAL REPLANTATION

Intentional replantation may be defined as the purposeful extraction of a tooth to repair a defect or cause of a treatment failure and then returning the tooth to its original socket. The individual first credited with the principle of extraction and replantation was an Arabian physician by the name of **Abulcasis (AbulKasim Al-Zahrawi, Fig. (1)** who practiced in the eleventh century **(936-1013)**.

Weine has stated that intentional replantation is only indicated when all other endodontic nonsurgical and surgical treatments have been performed and failed or were deemed impossible to perform.

Indications:

1. Nonsurgical and surgical endodontic procedures have been deemed impossible and the patient desires all possible efforts be made to retain the natural tooth.
2. Limited mouth opening that prevents the performance of nonsurgical or periradicular surgical endodontic procedures.
3. Root canal obstructions.
4. Nonsurgical and surgical treatments have failed and symptoms and/or periradicular disease persisted.
5. Resorptive or perforation root defects that exist on areas that are not accessible via the usual surgical approach without excessive loss of root length or alveolar bone.

Contraindications:

1. Teeth with long, curved roots that require a surgical extraction.
2. Teeth on advanced periodontal disease that has resulted in poor periodontal support and mobility.
3. Mutirooted teeth with roots that diverge making extraction and replantation impossible.
4. Teeth with nonrestorable caries.
   - The tooth should be kept out of the socket for the shortest time possible.
   - The periodontal ligament attached to the root surface should be kept in moist saline or in Hanks Balanced Salt Solution during entire time the tooth is out of the socket.
   - The extraction of the tooth should be accomplished as atraumatically as possible to minimize damage to the cementum and periodontal ligament.

Once the decision has been made and accepted by the patient to perform the intentional replantation procedure, any nonsurgical endodontic procedures should be completed to the best degree possible. The pulp chamber and coronal access are then restored to help stabilize and reinforce the coronal tooth structure during the extraction procedure.

Following extraction, the crown of the tooth should be wrapped in gauze moistened with saline or Hanks Balanced Salt Solution and held with the beaks of the forceps. It is also extremely important that the root surfaces be constantly bathed with one of these solutions during the entire extra-oral time. The roots are then thoroughly examined with magnification and a fiber optic light to evaluate for the presence of root fractures or periradicular perforation or resorptive defects.

If root-end resection is indicated, it should be accomplished perpendicular to the long axis of the root with the same bur and in the same manner as if the tooth was still in the socket. After root-end resection, the appropriate ultrasonic tip is used to create the small 3-mm-deep Class I root-end preparation. An appropriate root-end filling material will then be placed.

After the tooth has been inserted back into the socket, the patient is asked to bite so that the occlusion can be checked to assure the tooth is fully seated back into the socket.

Stabilization with a splint may not be required. If excessive mobility is present, splinting will be necessary. The recommended splinting type and length of time are the same as those for replantation of the traumatically avulsed tooth.

The patient should be re-evaluated 7 to 14 days following the intentional replantation to remove any stabilization that was placed and to evaluate tooth mobility. Other follow-up visits should be scheduled 1, 3, 6, and 12 months following the procedure.

IMPLANT SURGERY

OSSEOINTEGRATED IMPLANTS Fig. (20)

It is important to emphasize that while the surgical placement of osseointegrated implants is within the scope of endodontics, it is a very technique sensitive procedure. Attention to detail is required in the alignment of the implant so that it can be properly restored to maintain the health of the supporting periodontal tissues. Dentists who plan to incorporate this procedure into their practice should participate in advanced training programs in order to gain knowledge in diagnosis, treatment planning, and placement of osseointegrated implants prior to implementing their use in clinical practice.

Fig. 20. Photographs showing case of osseointegrated implant

ENDODONTIC ENDOSSEOUS IMPLANTS Fig. (21)

This type of implant is rarely ever used in today's practice of dentistry and will only be mentioned from a historical perspective. It seemed a good idea when the procedure was introduced because the rigid implant would be contained within the confines of the root canal system, extend into the apical bone to stabilize the tooth, and not have any direct communication with the oral cavity.

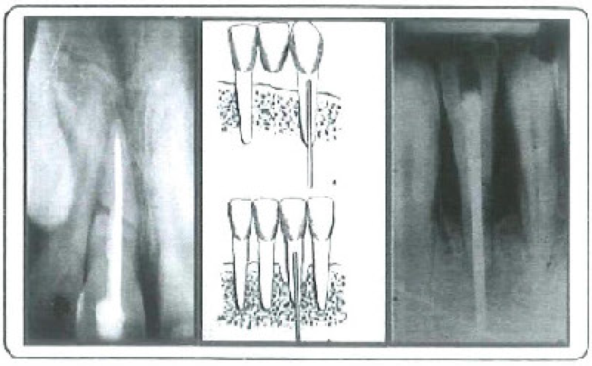


Fig. 21. Endodontic stabilizer and implant

MICROSURGERY

For years, many dental practitioners have benefited from the use of vision-enhancement devices, such as loupes, surgical telescopes, and head mounted surgical fiber optic lamps. It is generally accepted that the better the visual access to the operating field, the higher the quality of treatment that can be accomplished.

Perhaps one of the most important recent developments in surgical endodontics has been the introduction of the surgical operating microscope **Fig. (22)**.

Fig. 22. Loupes & surgical microscope

The advantages of the surgical operating microscope are:

1. Visualizing the surgical field.
2. Evaluating the surgical technique.
3. Reducing the number of radiographs needed.
4. Expanding patient education through video use.
5. Providing reports to referring dentists and insurance companies.
6. Creating documentation for legal purposes.

CHAPTER REVIEW QUESTIONS

1- Discuss the indications and contraindications of endodontic surgery.

2- Discuss the indications for incision and drainage and cortical trephination.

3- Enumerate the steps of periapical surgery

4- Discuss curettage, root-end resection and preparation in details.

5- Discuss different materials available for root-end filling.

6- Discuss the indications for corrective surgery

7- Give a brief account on replacement surgery.

8 Give a brief account on implant surgery .

9- Mention the advantages of microsurgery.

REFERENCES

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 5. 6th ed. BC Decker Inc ,2008.
- Hargreaves KM, Cohen S, Berman LH. 10th ed. St.Louis: Mosby Year Book; 2011. Cohen's Pathways of the pulp.
- Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod. 2006 Jul;32(7):601-23.
- Setzer FC1, Shah SB, Kohli MR, Karabucak B, Kim S. Outcome of endodontic surgery: a meta-analysis of the literature--part 1: Comparison of traditional root-end surgery and endodontic microsurgery. J Endod. 2010 Nov; 36(11):1757-65.
- Pecora GE, Pecora CN. A new dimension in endo surgery: Micro endo surgery. Journal of Conservative Dentistry: JCD. 2015;18(1):7-14.

21

Vital Pulp Therapy Preventive Endodontics

Randa El Baghdadi
Geraldine M. Ahamed

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify the indications, prognosis and procedures for vital pulp therapy.
2. Recognize the different forms of vital pulp therapy for primary and young permanent teeth.
3. Identify the situations in which a tooth with an open apex requires vital pulp therapy.
4. Explain how to perform root end closure and recognize the success or failure of treatment of an open apex.
5. Differentiate between the treatment of vital and non-vital teeth with open apex.

Master degree student should be able to:

1. Assess the different forms of vital pulp therapy for primary and young permanent teeth.
2. Apply different techniques of vital pulp therapy in different clinical situations.
3. Evaluate different materials used in vital pulp therapy.
4. Differentiate between the treatment options of vital and non-vital teeth with open apex.
5. Explain traditional techniques and new concepts in management of immature permanent teeth.

Ph.D student should be able to:

1. Evaluate and compare the different approaches for maintaining pulp vitality in immature permanent teeth.
2. Evaluate traditional techniques and new concepts in management of non-vital immature teeth (with open apex).

Chapter Outline

- Different forms of pulpal treatment for primary and young permanent teeth
  - Indirect pulp capping
  - Direct pulp capping
  - Pulpotomy
- Non vital pulp therapy
  - Apexification
  - Apical barrier
  - Revascularization

Vital pulp therapy is concerned with preservation (management) of the primary and young permanent teeth with pulp involvement. It aims to retain that tooth in a healthy condition so it may fulfill its role as useful component of the primary and young permanent dentition.

Importance of Pulp therapy

- Maintains arch length.
- Prevents abnormal habits.
- Maintains esthetics.
- Helps in mastication.
- Prevents infection.
- Prevents speech problems.
- Helps in timely eruption of permanent tooth.
- Allows normal root development and apical closure in young permanent teeth as loss of pulp vitality will lead to thin diverge and fragile root end and poor crown/root ratio.
- To relief pain immediately with uncooperative patients.

Different forms of pulpal treatment for primary and young permanent teeth include: (Fig 1)

I. Indirect pulp capping

II. Direct pulp capping

III. Pulpotomy

Indirect Pulp Capping

Indirect pulp capping is a procedure performed in a tooth with deep carious lesion adjacent to the pulp. In this procedure, caries near the pulp is left in place to avoid pulp exposure and is covered with biocompatible material.

Objectives

This procedure activates the tooth to use the natural protective mechanisms of the pulp against caries.

Theory and disagreement

The principles of indirect pulp therapy were recognized as early as 1850. It is based on the theory that a zone of affected demineralized dentin exists between the outer infected layer of dentin and the pulp. When the infected dentin is removed, the affected dentin can remineralize and odontoblasts form reparative dentin avoiding exposure.

Disagreement exists to whether the deep layers of carious dentin are infected. Those in favor suggested that, as the outer layers of carious dentin are removed most of the bacteria would be diminated from the lesion. When the lesion is properly sealed, the substrate on which the bacteria act to produce acid is also removed. So, with the arrest of the carious process the reparative mechanism is able to lay down additional dentin to avoid pulp exposure.

Indications

Teeth with minimal pulp inflammation in which complete removal of caries would probably cause pulp exposure.

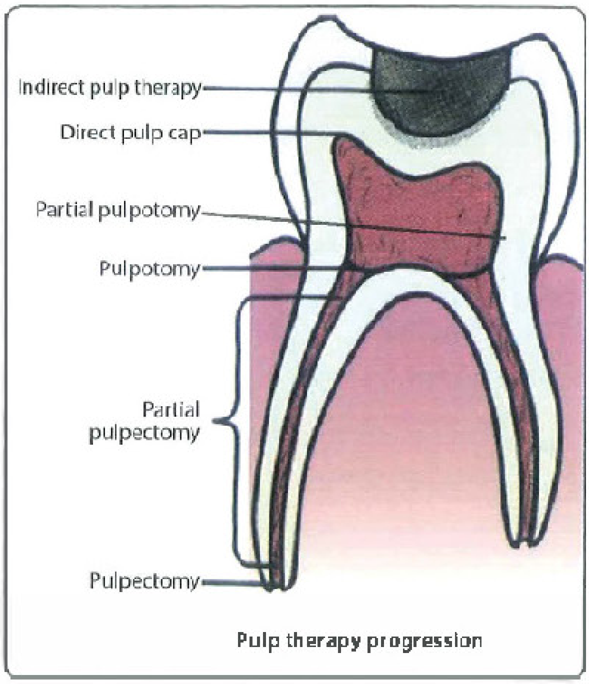


Fig. 1. Vital pulp therapy procedures

Contraindications

1. Presence of pulp exposure.
2. History of spontaneous toothache.
3. Tooth sensitive to percussion.
4. Mobility present.
5. Root resorption or periapical disease shown radiographically.

Indirect pulp capping agents:

The sedative dressing to be used in indirect pulp capping may be calcium hydroxide, zinc oxide and eugenol or glass ionomer cement.

Clinical Techniques

1. Careful diagnosis by radiograph and vitality tests should be done.
2. Band the tooth if the tooth is grossly decayed.
3. Anesthetize the tooth.
4. Apply the rubber dam to isolate the tooth.
5. Remove the soft caries either with spoon excavator or round bur.
6. Use fissure bur and extend it to sound tooth structure.
7. A thin layer of dentin and some amount of caries are left to avoid exposure. A spoon excavator could be used to remove caries near the dentino-enamel junction.
8. Place calcium hydroxide paste on the remaining carious dentin.
9. Cover the calcium hydroxide with zinc oxide eugenol.
10. If the restoration is to be left for a longer time, then amalgam restoration should be used. If the dressing is lost and the remaining caries is re-exposed to oral fluids, failure will occur.
11. The tooth should be evaluated after 6-8 weeks and the remaining caries removed.

Success

The success rate varies from 74% to 99% depending on case selection, length of study and type of investigation. Success could be investigated clinically, radiographically and histologically. When the tooth is re-entered the caries appears to be arrested. The color changes from deep red to light gray or brown and the texture changes from spongy and wet to hard and dehydrated. Inflammation will be resolved and deposition of reparative dentin beneath the caries will allow subsequent eradication of the remaining caries without exposure.

I) Direct pulp capping

Direct pulp capping procedure involves the placement of a biocompatible material over the site of exposure to maintain vitality of the pulp and promote healing.

When a small mechanical exposure of the pulp occurs during cavity preparation or following a trauma, an appropriate protective base should be placed in contact with the exposed pulp tissue so as to maintain the vitality of the remaining pulp tissue.

Objectives

The procedure activates a healthy pulp to initiate a dentin bridge to wall off the exposure site.

Indications

1. Small mechanical exposure of the pulp during cavity preparation or traumatic injury.
2. Teeth with pinpoint carious exposure surrounded with sound dentin.
3. Absence of signs of irreversible pulpal or periapical disease.

Contraindications

1. Wide pulp exposure. There is a general agreement that the larger the area of carious exposure the poorer the prognosis for pulp capping, as with larger exposures there is more pulpal tissue inflammation and more microorganisms invasion.
2. Teeth with periapical pathosis or the presence of fistula.
3. History of spontaneous pain.
4. Increased bleeding at the exposure site.
5. Purulent or serous exudate from the exposure site.
6. Periodontally affected teeth are also poor candidates because of diminished blood supply.
7. Exposures on the axial wall of the pulp as the pulp tissues coronal to the exposure site will undergo necrosis leading to failure.
8. Teeth with calcification in the pulp chamber and root canals indicate previous inflammatory response or trauma that render the pulp less responsive to therapy.
9. Normal aging of the dental pulp decreases chances of success due to increased fibrous and calcified deposits with reduction in fibroblasts proliferation and pulp volume.
10. Primary teeth with carious exposure.

Clinical Procedure

1. Administer local anesthesia.
2. Isolate the tooth with rubber dam.
3. Clean and dry the exposure site. In case of carious exposure, peripheral masses of caries have to be removed first; this prevents pushing of necrotic infected dentin into the exposed pulp which will interfere with healing. The area is washed with saline or sterile water, the dryness should be done with vacuum or cotton pellets. Air should be avoided to prevent dessication.
4. Apply calcium hydroxide over the exposed area and surrounding dentine.
5. Apply a creamy mix of zinc oxide eugenol over Ca(OH)2 and allow it to set completely, followed by a permanent restoration. Fig (2).

Any leakage to the capping material would cause failure.

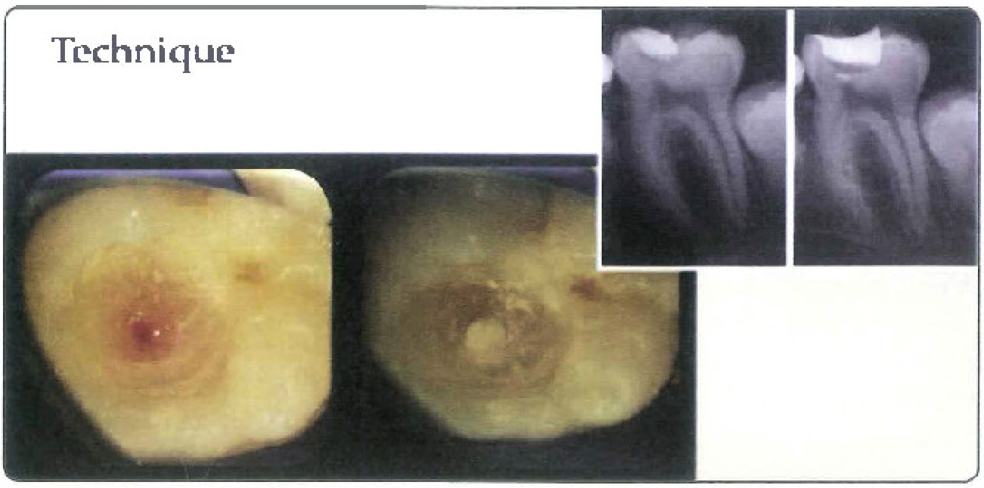


Fig 2. Direct pulp capping

Pulp capping agents

Many materials, medications, antiseptics, antibiotics, anti-inflammatory agents and enzymes have been employed as pulp capping agents, but calcium hydroxide and mineral trioxide aggregate (MTA)are generally accepted as the materials of choice.

Calcium Hydroxide Ca $(OH)_2$

- *Mode of action*

  The exact mechanism of Ca $(OH)_2$is not really understood. The Hydroxyl group is considered to be the most important component of Ca $(OH)_2$.

1. It allows it to maintain a local state of alkalinity (pH 11) that is necessary for bone and dentin formation, although compounds of similar alkalinity caused liquefaction necrosis when applied to ***the pulp***.
2. It neutralizes the lactic acid from the osteoclasts.
3. It activates alkaline phosphatase enzymes which play an important role in hard tissue formation.
4. Ca ions are an integral part of the immunological reaction and may activate the Ca dependent adenosine triphosphatase enzyme reaction associated with hard tissue formation.
5. It has a bactericidal effect.

When Ca $(OH)_2$ is applied directly to the tissues, it will cause:

1- Necrosis adjacent to the pulp tissues.

2 Inflammation of the contiguous tissue.

3- Dentin bridge formation occurs at the junction of the necrotic tissue and the vital inflamed tissue. Experiments with radioactive ions proved that Ca in dentin bridge comes from the blood stream and not from Ca $(OH)_2$. The calcified tissue produced from the odontoblasts and connective tissue cells was histologically identified as a porous layer of osteodentin.

- *Drawbacks of Ca (OH)2:*

  Occasionally in spite of successful bridge formation:

a- The pulp remains chronically inflamed or becomes necrotic.

b- Internal resorption may occur following capping.

c- Complete dentin mineralization of the remaining pulp tissue occludes the canals to the extent that they cannot be penetrated for endodontic therapy if needed.

MTA

Biodentin

Biodentin is a biocompatible material, capable of inducing the apposition of reactionary dentin by stimulating odontoblast activity by induction of cell differentiation.

MTA is a new biocompatible pulp capping agent with a pH 12.5. It produces more dentinal bridging in a shorter period of time with less inflammation and superior sealing.

Success of the procedure could be investigated clinically, radiographically and histologically. The tooth should be asymptomatic and pulp should maintain its vitality without any sign of degeneration or periapical disease. Young permanent teeth should show continuous root development. Although formation of dentin bridge has been used as one of the criteria for

judging success, bridge formation may occur in teeth with irreversible inflammation. More over successful pulp capping has been reported without the presence of the dentin over the exposure site.

III) Pulpotomy

Pulpotomy refers to amputation of the vital inflamed pulp from the coronal chamber followed by medicament placement over the radicular pulp stump, to fix or stimulate repair of the remaining vital pulp tissue.

Objectives of Pulpotomy

1. To preserve the vitality of the pulp.
2. To promote apexogenesis by retaining the vitality of the pulp in the canal of an immature young permanent tooth.
3. To provide pain relief in case of acute pulpitis.

Rationale of Pulpotomy

Bacterial contamination causes inflammatory response in the pulpal tissue. This inflammation transmits from coronal to the apical part with time. The rational of pulpotomy is to save the remaining pulp when only the superficial part is involved. This preserves the vitality of the pulp.

This practical excision of pulp, i.e. pulpotomy offers the following advantages over the complete removal of pulp i.e pulpectomy:

a- Preserves structural integrity of tooth.

b Pulpectomy in young permanent tooth can interrupt growth of the root, resulting in short root without apical constriction.

Criteria for Successful Pulpotomy

1. The tooth should be asymptomatic.
2. The tooth should respond to pulp testing.
3. No radiographic signs of periradicular periodontitis.
4. No indication of root resorption.

Indications

1. Young permanent teeth with vital exposed pulp and incompletely formed roots.
2. Primary teeth with pulp exposure in which inflammation or infection is judged to be confined to the coronal pulp.

Contraindications

1. Non restorable tooth.
2. A history of spontaneous pain.
3. Evidence of periapical pathosis or presence of fistula.
4. A pulp without hemorrhage following pulp exposure.
5. Inability to control hemorrhage following coronal pulp amputation.
6. A pulp with serous or purulent discharge.
7. A primary tooth near exfoliation or with no bone overlying permanent tooth crown.

Pulpotomy agents:

$Ca(OH)_2$ is considered the material of choice in pulpotomy in young permanent teeth due to its high success rate.

Concerning primary teeth studies showed that **formocresol** pulpotomy has a higher success rate than $Ca(OH)_2$.

Clinical Techniques

1. Give adequate local anesthesia in the area.
2. Apply the rubber dam to isolate the tooth.
3. Remove infected dentin before entering pulp chamber either with round bur or spoon excavator.
4. Extirpate the coronal pulp down to pulp stump at the orifice of the canals with the help of round bur or spoon excavator.
5. Apply gentle pressure with moistened cotton pellets to arrest pulpal hemorrhage.

6. When hemorrhage is controlled:
   - A dressing of Ca(OH)2 is placed over the amputation site in permanent teeth
   - A dressing of 1/5 formocresol on a cotton pellet is placed in direct contact with the pulp stump for 5 minutes, in formocresol pulpotomy. When the cotton is removed the tissues should appear brown and no hemorrhage should be present.
7. In case of Ca(OH)2 pulpotomy a creamy mix of ZOE must be placed over the Ca(OH)2 and allowed to set completely. In case of formocresol pulpotomy a cement base of ZOE is placed over the pulp stump and allowed to set. The tooth may then be restored permanently.

Formocresol

Formocresol pulpotomy is considered to be the treatment of choice for primary teeth with vital carious exposure of the pulp. This is due to its ease of use and excellent clinical success.

Nevertheless formocresol pulpotomy has been reported as a temporary treatment on permanent teeth with irreversibly inflamed pulps until endodontic treatment is advocated at a later date.

The use of formocresol has been controversial issue since there has been many reports about its wide distribution and its potential toxicity, allergenicity and carcinogenicity.

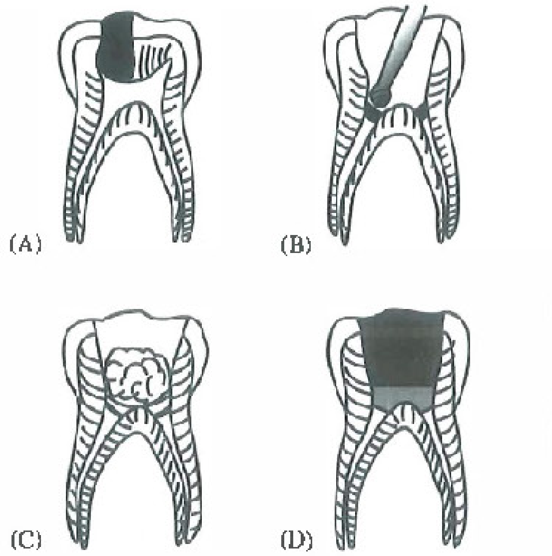
Mode of action:

Formocresol has the ability to prevent autolysis of tissues by complex chemical binding with the intermediate end product of inflammation to form a colorless non-infective tissue of harmless nature.

Immediate effect: within few minutes of application it shows a surface area of fibrosis.

After 4-7 days: 3 distinct zones become evident:

- A zone of fixation close to the material followed by,



A. Decay exposing and infecting the pulp chamber.
B. Removing infected coronal pulp tissue.
C. Treat chamber with medicine on cotton balls.
D. Fill chamber with paste filling.

Fig. 3. Steps of pulpotomy

- A zone of atrophy, then
- A broad zone of chronic inflammatory cells diffusing apically into the normal pulp tissues.

After 60 days to one year: the entire pulp becomes fibrous.

Other materials used for pulpotomy

- *Glutaraldehyde*: Due to the systemic effect of formocresol, glutaraldehyde has been suggested as a possible replacement for pulpotomy on primary teeth. Aqueous glutaraldehyde 2% to 4% produces rapid surface fixation to the tissues directly below the area of application. It has less penetration effect to the underlying tissues. The rest of the pulp tissues remain vital and free from inflammation. The advantage of glutaraldehyde over formocresol:

a- It does not perfuse the pulpal tissue to the apex.

b- It demonstrated less systemic distribution immediately after application.

c- The drug is limited largely to the pulp space, with little evidence of escape outside the tooth following pulpotomy.

The indications, contraindications and technique for glutaraldehyde pulpotomy are the same as formocresol pulpotomy.

Success:

Clinical success is judged by:

1. Absence of any clinical or radiographic sign of pathosis.
2. The presence of continued root development in young permanent teeth with incomplete roots.
3. Unlike Ca(OH)2 pulpotomy, with formocresol no dentin bridge occurs.

Signs of failure:

1. Clinically: pain, swelling, mobility, fistula.
2. Radiographically: radiolucency at the furcation, apex or lateral to the root.
3. Internal / external resorption of the root.

Controversy

Should pulp capping and pulpotomy be considered as permanent treatment in immature permanent teeth?

- *NO:* Once root formation is completed, routine endodontic treatment may be performed.
- *YES:* No need to do routine endodontic treatment unless there are pathological changes.

Factors affecting outcome of vital pulp therapy

1. Pulp status
2. Age of the patient
3. Restorative plan
4. Control of microorganisms
5. Size of exposure
6. Material used for vital pulp therapy
7. Operator experience

Non vital pulp therapy

I. Apexification

II. Apical barrier technique

III. Revascularization

IV) Apexification

Apexification is the induction of a calcified barrier (or the creation of an artificial barrier) in an immature pulpless tooth with an open apex. It is different from apexogenesis in that in the latter, root development occurs by physiological process.

In young permanent teeth with necrotic pulp and incompletely formed roots, apexification is advantageous over the conventional root canal treatment because:

a. The apex is funnel shaped with the apical part wider than coronal part.
b. The canal walls are thin and fragile.
c. Absolute dryness of the canal is difficult to achieve.

Objectives of apexification

The main objective of apexification is to achieve an apical stop for obturating material. This apical stop can be obtained by:

a. Inducing natural calcific barrier at the apex or short of apex.

b. Forming an artificial barrier by placing a material at or near the apex.

c. Inducing the natural root lengthening by stimulating the Hertwig's epithelial root sheath.

While the apexification procedure is highly successful, the root of such a tooth is weak. Therefore, apexification should be the treatment of last resort after all attempts of vital pulp therapy have failed. Figs. (4,5)

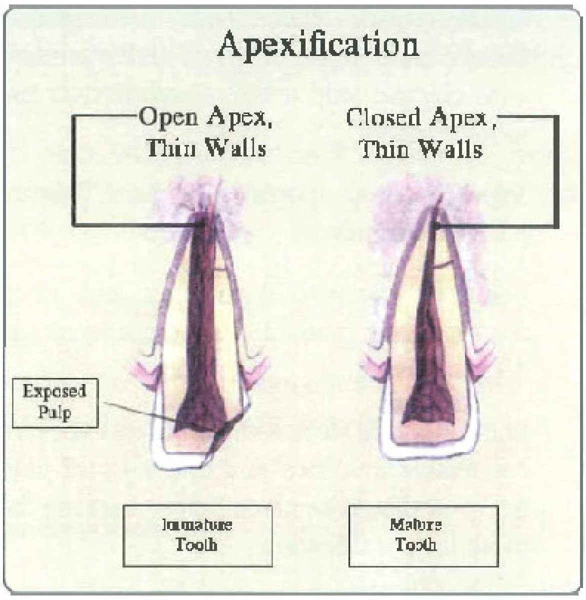


Fig. 4 Apex of mature and immature teeth

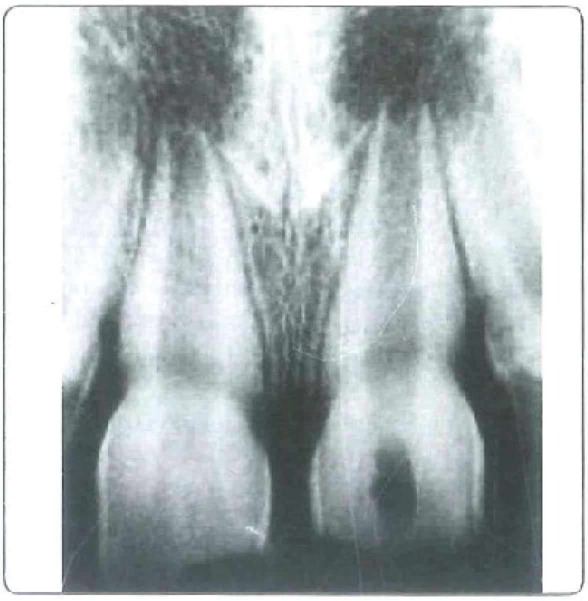


Fig. 5. A radiographic picture showing anterior immature permanent teeth

Indications

1. Non vital immature teeth.
2. Failure of apexogenesis.

Contraindications

a. All vertical and most horizontal root fractures.

b. Very short roots.

Before the introduction of the apexification technique the open apices were surgically treated. The disadvantages of the surgical method of treatment are mechanical and physiological:

A- Mechanical:

1. Difficulty in achieving apical closure due to the thin fragile apical dentin walls.
2. Poor crown/root ratio.

B- Psychological: As most of the patients who need this treatment are children, surgical approach can cause psychologic trauma.

Diagnosis

Unless a frank exposure of the pulp chamber exists, diagnosis of pulp necrosis in a tooth with incompletely formed apex is sometimes difficult.

1. History taking: most cases are due to trauma.
2. Radiographic examination: is complicated because of the normal radiolucency at the apex of maturing roots. Comparison with the contralateral tooth is indicated.

3. Vitality tests: teeth with incompletely formed roots will not give reliable reading with electric pulp tester. Thermal tests are more reliable.

4. Type of pain: spontaneous pain denotes pulpal involvement.

5. Percussion sensitivity,mobility and tooth discoloration should be considered in diagnosis.

   In traumatized teeth without pulpal exposure conclusive evidence and diagnosis of pulp necrosis should be made before opening the tooth for apexification.

Materials used for apexification

Many materials have been reported to successfully stimulate apexification:

- **$Ca(OH)_2$:** It can be used alone (mixed with saline, distilled water or anesthetic solution) or in combination with other drugs like: Camphorated paramonochlorophenol CMCP (antimicrobial activity will continue to clean the canal and high pH encourage calcific root end closure).
- **MTA (Mineral Trioxide Aggregate)**
- **Other materials:** Calcium phosphate (tri-calcium phosphate TCP, hydroxyappatite HA), zinc oxide paste, collagen calcium phosphate gel in which the gel appears to function as an absorbable matrix to support apical hard tissue growth.

Technique

1. Anesthetize the tooth and isolate it with the rubber dam.
2. Prepare the access opening larger than normal to facilitate removal of all necrotic tissue.
3. Remove all remnants of necrotic pulp from the canal and irrigate it with sodium hypochlorite.
4. Establish the working length of the canal. The final working length should be adjusted 2 mm short of the radiographic apex.
5. Complete cleaning and debridement of the canal, irrigate and then dry the canal. The main reason for biomechanical preparation is debridement and not shaping of the canal. Because the canal is already very wide, care should be taken not to further thin down the fragile dentinal walls.
6. When the tooth is free of signs and symptoms of infection, dry the canal and fill it with a thick mix of Ca(OH)2 . The paste can be carried to the canal with an amalgam carrier, lentulo spiral, disposable syringe or an endodontic pressure syringe. It is then gently packed to the apex with pluggers.
7. Check radiographically that the whole canal is packed with Ca(OH)2 paste.
8. Seal the access opening with a permanent filling material.

***Periodic recall** (follow up)*

The usual time required for apical closure to occure is 6-24 months. The patient is recalled at 3 months intervals to monitor apical closure. Evidence of apical closure should be checked radiographically as well as clinically. Clinical verification is made when a small instrument fails to penetrate through the apex after removal of Ca(OH)2 paste. If apexification is incomplete, the canal is repacked with Ca(OH)2 and periodic recall continued.

Obturation

Obturation in such teeth using lateral condensation is not advocated because the lateral pressure

during compaction of guttapercha may fracture the teeth. In such teeth, customized guttapercha point has to be used. Thermoplasticized guttapercha technique is preferred in order to improve adaptation in irregular and diverging canals.

Restoration

Since, the dentinal walls are weak in such cases; restoration should be designed to strengthen the tooth. To strengthen the root, guttapercha should be removed below the alveolar crest, the dentin is acid etched and composite resin is applied. Placement of posts in such cases should be avoided.

Histology of apexification

Histologic studies of teeth with immature apices reported the absence of Hertwig's epithelial root sheath, so normal root formation usually does not occur after apexification. The adjacent connective tissue cells differentiate into specialized cells and deposit calcified tissue adjacent to the filling material and continuous with the lateral tooth surface. The calcified material that forms over the apical foramen has been histologically identified as osteoid (bone like) or cementoid (cementum like) material.

Apical barrier technique

Recently an artificial root end barrier technique at a single visit using MTA has been advocated. MTA is packed into the canal with pluggers, so creating an immediate sealing and a biocompatible barrier against which the filling material can be packed.

To place MTA in the canal isolate the tooth, mix MTA and compact it to the apex of the tooth creating a 2mm thickness plug. Take a radiograph to confirm its placement. Since MTA needs moisture for setting, the cavity is sealed with moist cotton pellet. After 48 hours, confirm the final set of MTA, and obturate the remaining canal using gutta percha. Fig. (6)

Revascularization

It is a technique where non vital immature teeth are encouraged to grow new pulps and complete root formation (length and wall thickness).

Revascularization protocol:

The canal is disinfected with copious irrigation with 5.25% NaOcl, dried and medicated with freshly mixed paste of ciprofloxacin and metronidazole and sealed.

After 1-2 weeks, the canal is opened, irrigated and overinstrumented to create bleeding up to the cervical level.

The blood clot is overlaid with MTA and composite and forms scaffold for invasion by SCAP (stem cells of apical papilla) cells.

Pulp regeneration will allow continued root formation in previously pulpless tooth.

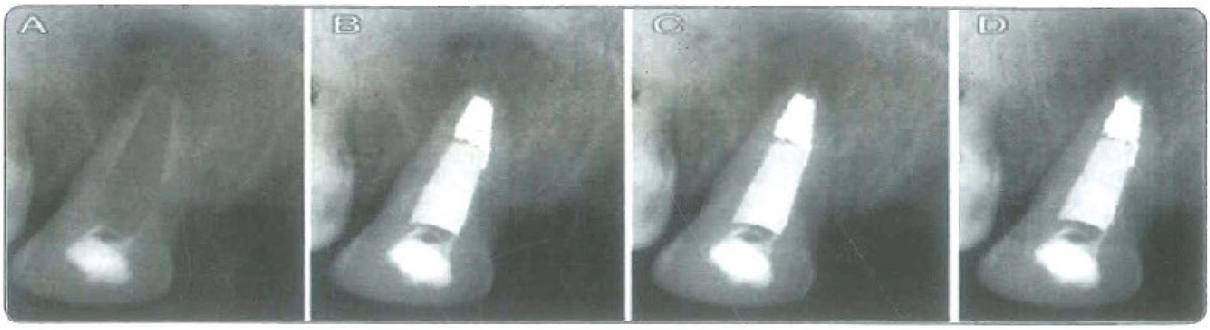


Fig.6. A radiographic picture showing MTA plug

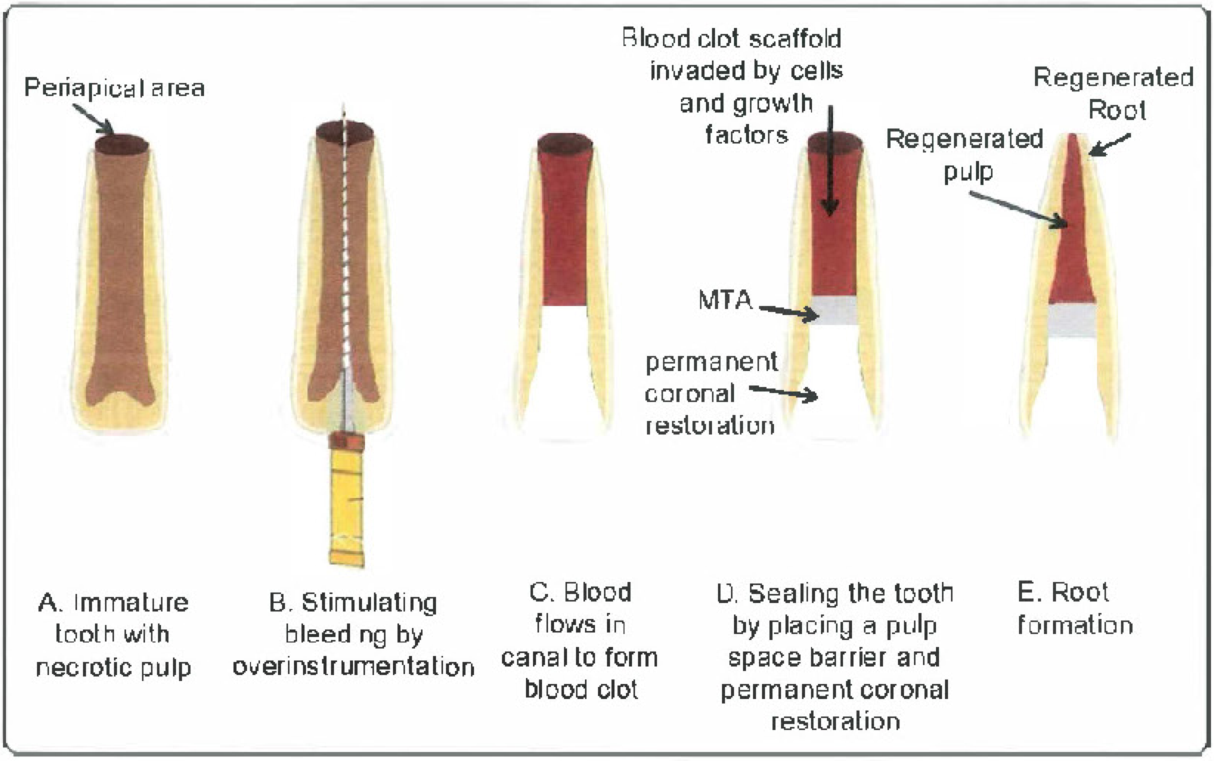


Fig.7. Revascularization protocol after 1-2 weeks of antibiotic medication

Chapter review Questions

1. Define vital pulp therapy and discuss the importance of retaining the young and permanent teeth in healthy condition in the dental arch
2. Mention the factors affecting the outcome of the vital pulp therapy
3. Calcium hydroxide is considered a pulp capping material. Discuss its mode of action and drawbacks.
4. Describe the indications and contraindications of pulpotomy in young permanent teeth.
5. Discuss the different treatment plans of a necrotic immature anterior tooth.

References

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6 6th ed. BC Decker Inc.,2008.
- Ward J. Vital pulp therapy in cariously exposed permanent teeth and its limitations. Aust Endod J. 2002; 28: 29-37.
- Bergenholtz G, Spangberg L. Controversies in endodontics. Crit Rev Oral BioMed. 2004; 15: 99-114
- Aguilar P, Linsuwanont P. Vital pulp therapy in vital permanent teeth with cariously exposed pulp: A systematic review. J. Endod. 2011; 37: 581-7
- Hargreaves KM, Cohen S, Berman LH. 10th ed. St.Louis: Mosby Year Book: 2011. Cohen's Pathways of the pulp.
- Cohenca N, Paranjpe A, Berg J. Vital pulp therapy. Dent Clin North Am. 2013; 57: 59-73

22 Application of Therapeutics in Endodontics

Maged Negm

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify the cases in need for therapeutic treatment in dentistry.
2. Determine medicaments employed for treatment of anxiety.
3. Determine therapeutic treatment of pain.
4. Determine non steroidal anti-inflammatory agents.
5. Differentiate non-narcotic from narcotic analgesics.
6. Describe mechanisms of bacterial resistance to antibiotics.
7. Describe mechanisms of antibiotic action.
8. Recognize antibiotic toxic and allergic effects.
9. Identify different types of antibiotics.
10. Recognize types of penicillin.
11. Understand the structure, spectrum, effects, adverse effects, administration and doses of cephalosporins, erythromycins, clindamycins, tetracyclines and metronidazole.

Postgraduate students should be able to

1. Criticize narcotic vs. non-narcotic analgesics.
2. Assess different drugs used for control of anxiety.
3. Compare different types of penicillin with different types of broad-spectrum penicillin.
4. Select the proper antibiotic according to patient's illness and body condition.
5. Assess mechanisms of action of antibiotics and forms of bacterial resistance to antibiotics.

Chapter Outline

CATEGORIES

Antianxiety

Analgesics

Antibiotics

THE CHALLENGE

Differentiation of medical conditions and their therapeutic treatment.

Classification of medical cases and list of the drugs specified for treatment of each case.

Management of anxiety, pain and infection

Drug actions and interactions and adverse effect.

Cases requiring therapeutic treatment in endodontics are:

ANXIETY
PAIN
INFECTION
ANXIETY is treated by PHARMACOSEDATIONS
PAIN is treated by ANALGESICS
INFECTION is treated by ANTIBIOTICS

ANXIETY

ANXIETY is defined as TRUE FEAR
TREATMENT:

1. Benzodiazepines.
2. Sedative – hypnotics.
3. Antihistaminics.

BENZODIAZEPINES

- Diazepam (Valium).
- Chlordiazepoxide (Librium).
- Oxazepam (Serax).
- Lorazepam (Ativan).
- Flurozepam (Dalman).

DIAZEPAM (VALIUM)
Pharmacologic effects:

1. Antianxiety.
2. Anticonvulsant.
3. Sedative – hypnotics.
4. Skeletal muscle relaxant.
5. Amnesic.

Well absorbed from G.I. tract.
Administration: oral I.V.- I.M.
Adult oral dose: 2-10 mg.

Adverse effects:

- Drowsiness.
- Ataxia .
- Motor impairments.
- CNS depression.
- Dizziness.
- Drug dependence.

Contraindications:

- Allergy.
- Glaucoma.
- First trimester of pregnancy.

SEDATIVE – HYPNOTICS

1- BARBITURATES
2- NON-BARBITURATES

SEDATION means CALMING
HYPNOSIS means SLEEPING

BARBITURATES

- Pentobarbital (Nembutal).
- Secobarbital (Seconal).
- Phenobarbital (Luminal).
- Methohexital (Brevital).

Administration: Oral – Rectal – IV – IM
Adult dose: 100 – 200 mg

Barbiturates are dose-dependent.
Begins with Sedation then Hypnosis, Anaesthesia and then Death (respiratory depression)
Adverse effects:

- Psychological dependence.
- Physical dependence.
- Fall in heart rate.
- Fall in blood pressure.
- Respiratory depression.

Contraindications:

- Allergy.
- Respiratory distress.
- Liver damage.

NON BARBITURATES

Drugs that are not chemically related to barbiturates and possess sedative – hypnotic properties.

Differ from barbiturates in two aspects:

1. Less potent.
2. Not cross-allergenic with barbiturates.

Possess the same adverse effects as barbiturates.
ANTIHISTAMINES

- **Benadryl.**
- Phenergan.
- Atarax.
- Avil.
- Analerg

Administration: oral – IM – IV.

Adverse effects:

- Dizziness.
- Drowsiness.
- Motor incoordination.
- Blurred vision.
- CNS depression.

NITROUS OXIDE-OXYGEN PHARMACOSEDATION.
Colourless inorganic gas compressed into liquid.
Non-irritating to mucosa.
Sweet odour.
Rapid onset of action (3-5 min).
Rapid recovery.
Ease of administration.
Small traces may be detected in the operating room.

Subjective symptoms:
- Euphoria
- Dreaming.
- Drowsiness.
- Mental and physical relaxation.
- Indifference to surroundings and passage of time.
- Lessened pain awareness.
- Feelings of warmth.
- Tingling sensation in the extremities (fingers, tongue & lips)
- Heaviness of chest.
- Distortion of sounds (seem distant).

Adverse effects:
- Nausea.
- Vomiting.
- Perspiration.
- Behavioral alterations.

Contraindications:
- History of psychosis.
- Migraine.
- Headache.
- Prolonged drug abuse (neurologic damage).

ANALGESICS

Drugs having the ability to raise the pain threshold at a subcortical level.

NON NARCOTICS
NARCOTICS
NON-NARCOTIC ANALGESICS
- Non steroidal anti-inflammatory agents NSAIAs or NSAIDs.
- Antipyretic analgesics.

Prostaglandins

Prostaglandins (PGs) are responsible for the inflammatory process with its signs and symptoms. The cyclooxygenase enzyme systems (COX) produce prostaglandins. The cyclooxygenase (COX) enzyme systems are mainly present in the form of COX-1 and COX-2.

COX-1 inhibitors produce gastro-intestinal irritation and ulceration. COX-2 inhibitors produce cardio-vascular problems. Therefore, for safety, manage pain with non-COX-2 selective drugs whenever possible.

NON-NARCOTIC ANALGESICS
1. **Non-steroidal anti-inflammatory agents (NSAIAs)**

Group of drugs:
- Differing in chemical structure
- Sharing pharmacologic and toxic properties.

Pharmacologic properties of NSAIDs.
- Analgesic.
- Antipyretic.
- Anti-inflammatory.
- Anti-rheumatic.

Toxic properties of NSAIDs.
- Allergy.
- GI. irritation.
- Bleeding.
- Liver damage.

ASPIRIN
(Acetyl salicylic acid)
Mode of action :
1. Hypothalamus.
2. Peripheral vasodilatation.

Aspirin works on hypothalamus decreasing synthesis of prostaglandin and hence decreasing its pain sensitizing effect and inflammatory effect, which possess pain sensitizing effect and inflammatory effect.

Well absorbed from the upper part of small intestine.
Metabolized in the liver.
Food slows its rate of absorption but not its effect.

ASPIRIN IS AN:
Analgesic - Antipyretic – Antiinflammatory – Antirheumatic – Keratolytic.

Adverse effects:
1. GI. irritation.
2. Allergy.
3. Bleeding (decrease platelets agglutination).
4. Analgesic nephropathy (renal endothelial damage).
5. Liver toxicity (liver damage).
6. Aspirin intolerance.
7. Salicylism (intoxication).
8. Teratogenic effect.
9. Drug interactions.

Aspirin intolerance syndrome:
Urticaria Angioedema Bronchospasm - Severe rhinitis – Shock.
Occur within 3 hours.
Salicylism (intoxication):
Headache – Dizziness – Tinnitus – Drowsiness - Nausea – Vomiting.

Teratogenic effect:
- Prolongs pregnancy and labour.
- Decreases birth weight.
  FDA warning against the use of ASPIRIN in the 3rd trimester.

Drug interaction:
- ASPIRIN given with NSAIDs causes severe bleeding and ulceration.
- ASPIRIN given with corticosteroids potentiates gastro-intestinal ulceration.
- ASPIRIN inhibits vitamin C action.
- ASPIRIN given to alcoholics produces gastric hemorrhage.
- ASPIRIN potentiates penicillin action.

Contraindications:
- Allergy.
- Peptic ulcer.
- Bleeding tendency.
- Renal failure.
- Asthma.
- Systemic lupus erythematosis.

Ibuprofen (Motrin, Advil)
Analgesic – Antipyretic – Antiinflammatory – Antirheumatic.
Well absorbed when taken orally.
Food delays rate but not total amount absorbed.
Excreted via kidneys as metabolites.
Adverse effects:
- GI. irritation (only half as common as with aspirin).
- Epigastric pain.
- Anorexia.
- Nausea.
- Vomiting.
- Dizziness.
- Vertigo.
- Headache.

Contraindications:
- Allergy.
- Peptic ulcers.

Dexketoprofen (Dextrafast)
An isomer of ketoprofen with similar effect, but with half dose only. Rapid onset of action and greater analgesic efficacy in the first hour. 50% reduction in dosage and hence reduces renal load.
Dose: 25mg/ 8 hours.

Diflunisal (Dolobid):
Derivative of Salicylic acid and possesses the same pharmacologic and toxicologic properties of NSAIAs.
Long-term duration of action (8-12 hours), however it has a slow onset of action (3 hours).
Contraindicated in patients with aspirin intolerance.

Piroxicam (Feldene):
Belongs to the group of Oxicams. Food slightly delays the rate but not the extent of absorption. Administration could be oral-rectal or intramuscular.
Adult dose: 10mg/12 hours or 20 mg/24 hours.

Long acting & relatively stable
Can be taken in a single daily dose.
Non SELECTIVE COX

Diclofenac (Voltaren- Cataflam- Diclac-Arthrofast):
Well absorbed orally. Can also be taken parenterally.
The same effects, adverse effects and indications like the rest of NSAIDs.
Dose 50-100 mg/8hours.

Relatively COX-2 SELECTIVE

Chemical structure benzenesulfonamide.

Eliminated mainly through the liver. Supplied in the form of oral capsules of 100-200mg.

Contraindicated to patients allergic to sulfonamides and aspirin.

This drug should not be prescribed to cardiac patients.

Adult dose:200-400mg/day

COX-2 SELECTIVE.

2. Antipyretic analgesics acetaminophen
Analgesic & antipyretic
Introduced as an aspirin substitute.

Marketed under more than 200 formulations
The most known one is Tylenol

- Does not cause GI. Irritation.
- Does not affect platelet aggregation.
- Does not affect prothrombin synthesis.
- Rarely causes allergy.

 Absorption in the small intestine.
 Food decreases the rate but not total amount absorbed.
 Detoxified in the liver.

Adverse effects:

- Urticaria
- Hypoglycaemia
- Jaundice
- CNS disturbance (stimulation or depression).
- The most serious effect is severe, fatal hepatic necrosis with high doses.

Contraindications:

- Impaired hepatic function.
- Impaired renal function.
- Anaemic patients.
- Chronic alcoholism.

NARCOTIC ANALGESICS
These drugs work on the narcotic receptors in the CNS.
Narcotics may also be used to refer to Opium or Opiates

MORPHINE:

Natural constituent of opium along with narcotine, papaverine & codeine.

Well absorbed parenterally –but poorly absorbed orally.

Adult dose is 5-20mg.

Morphine is the drug of choice for severe pain: Postoperative pain, traumatic pain, accidental pain and neoplastic pain.

Effects &adverse effects:

1- Analgesia
2- Sedation
3 –Euphoria
4- Dysphoria
5- Emesis
6 Constipation
7- Miosis
8- Nausea
9- Vomiting
10- Dizziness
11- Drowsiness
12- Tennitus
13- Narcosis
14- Convulsions
15 Headache
16 Histamine release
17- Respiratory depression
18- Cough suppression
19- Mood alteration
20- Mental clouding
21- Delirium
22- Insomnia
23- Sweating
24 Flushing
25- Hypotension
26- Allergy
27- Hallucination
28- Coma
29- Psychic dependence
30- Physical dependence
31- Tolerance
32- Asthma
33- Respiratory depression
34-Circulatory depression

Contraindications:
- Head injury
- Increased intracranial pressure
- Asthmatics
- Allergy

Methadone:

Well absorbed both orally and parenterally (IM or subcutaneously).

Adult dose 2.5-10mg IM,SC,orally.

Effects, indications and contraindications are comparable to morphine.

Contraindicated under the age of 18 years.

Well absorbed both oral and parenteral.

Metabolized in the liver.

Adult dose 50-100 mg.

Possesses atropine like effects and, hence, contra indicated with glaucoma and prostatic patients.

Effects, adverse effects and contraindications are similar to morphine.

HYDROMORPHONE (Dilaudid):
Synthetic derivative of morphine.
8 times more potent than morphine.
Adult dose 2mg oral or parenteral.
Pharmacologic effects and adverse effects are similar to morphine.

CODEINE:

Commercially synthesized from morphine.

Pharmacologic effects are qualitatively similar but quantitatively less than morphine.

Well absorbed both orally and parenterally.

Drug of choice for cough suppression.

Adult dose 15-60 mg.

TRAMADOL
Used for short lasting as well as chronic pain.
Oral – parenteral.IV. 100mg Tramadol = 10mg morphine.

ANTIBIOTICS

Antibiotics are indicated for:

Treatment and prevention.

Mechanisms of bacterial resistance to antibiotics:

Drug tolerance or drug destruction

Forms of bacterial resistance to antibiotics are:

- Presence of an outer phospholipid covering prevents access of antibiotics to their site of action within the microorganism.
- Deposition of a protein protective layer to the cell wall.
- Alteration in the enzymatic target sites for antibiotics.

Resistance to antibiotics is achieved by one of three approaches:

1. Natural (mutational): spontaneous, random mutation of bacterial genes independent of contact to antibiotics.
2. Acquired: occurs in presence of contact with antibiotics.
3. Transferred (infectious): conferring resistance from an antibiotic-resistant bacterium to an antibiotic-sensitive bacterium.

Mechanisms of action of antibiotics:

- Suppression of bacterial protein synthesis.
- Inhibition of cell wall formation and possible induction of autolysis.

Steps of prophylactic use of antibiotics:

1- Diagnose the disease and type of microorganism.
2- Choose the specific antibiotic against this organism.
3- Select the proper dose.
4- Begin antibiotic administration 1 to 2 hours prior to procedure.
5- Extend duration of drug administration to the proper period.

General antibiotics toxic and allergic effects:

1. Direct toxicity.
2. Allergy.
3. Biologic and metabolic alteration in the host.

- Penicillins and cephalosporins: free from direct toxicity.
  Yet they are highly antigenic (allergenic).
- Erythromycin have Direct toxicity.
  Yet it is extremely low allergenic.
- Tetracyclines have direct toxicity (liver damage – tooth discoloration).
  However they are moderately allergenic.
- Bacitracin and polymixin B have direct toxicity (severe renal damage).

ANTIBIOTIC AGENTS
PENICILLINS

A generic term for closely- related antibiotics that differ in:

1. Antibacterial spectrum.
2. Resistance to gastric acid.
3. Destruction by beta-lactamase (penicillinase) enzyme.

Classification:

1- Natural (penicillin G).
2- Semi-synthetic (penicillins V).

PENICILLIN G

The only completely natural penicillin used clinically.

Spectrum:

Generally effective against: Gram +ve and gram –ve cocci.

Most anaerobic organisms.

Organism resistant:

Most Gm –ve bacilli.

Enterococci.

Staphylococci of community and hospital variety.

When orally administered 2/3rds or $3/4^{th}$ are destroyed in the stomach.

Actively secreted by the kidneys.

Adverse reactions:

Penicillin is the most commonly allergenic of all drugs.

Allergenic reaction to penicillin can be classified into:

1. Immediate (within 20 minutes): characterized by urticaria and anaphylactic shock.
2. Accelerated (2 to 48 hours): urticaria, fever and laryngeal oedema.
3. Late (3days and longer): urticaria, serum sickness, artharlgia, anemia, purpura and erythema multiform.

Penicillins are cross allergenic

PENICILLIN V

Semisynthetic penicillin.

Simillar to penicillin G.

Stable and resistant to gastric acid.

Approximately 65% of the drug absorbed when taken orally.

Broad-spectrum penicillins

Ampicillin - Amoxycillin

- Both have similar antibacterial spectrum.
- Amoxycillin is absorbed better & produces less diarrhea.
- Bactericidal against many Gm +ve and Gm –ve aerobic and anaerobic bacteria.
- Some of them are mixed with antipenicillinase or anticephalosporinase enzyme such as:
- Augmentin (amoxycillin + clavulanic acid)
- **AUGMENTIN**
- **(Amoxycillin+ clavulanic acid)**

Amoxycillin effective against

Gm+ve aerobes and anaerobes

Gm-ve aerobes and anaerobes

Clavulanic acid is effective against B-lactamase.

Adult dose: tablets 500-1000mg/12 hours.

Syrup & IM. injection are also available.

UNASYN(Sultamicillin)

Ampicillin + Sulbactam (B-lactam inhibitor) Sultamicillin.

Excreted unchanged in the urine.

Adult dose: tablets 375-750mg / 12 hours.

Suspension 250mg (one teaspoonful) / 12 hours.

CEPHALOSPORINS

Broad spectrum group.

Classified as 1^{st} – 2^{nd} – 3^{rd} – 4^{th} generations

Sensitive to beta-lactamase enzymes such as Cephalosporinase.

Spectrum:

Streptococcus and staphylococcus organisms.

Most anaerobic species.

Gm +ve are more sensitive than Gm –ve.

Administration:

Oral: Cephalexin (Keflex).

Cefaclor (Ceclor).

Cefadroxil.

Oral and parenteral → Cephradine (Velosef).

Most of Cephalosporins are excreted unchanged by the kidney within 6 hours.

Adult dose 250-500mg/ 6 to 8 hours.

Children 125mg syrup.

Adverse effects:

Cross allergy between penicillins and cephalosporins being closely related chemically.

Skin rash – fever – serum sickness – eoxinophilia.

ERYTHROMYCIN

Either bactericidal or bacteriostatic depending on microorganism and concentration.

Destroyed by gastric acid and, hence, it is enteric-coated.

Detoxified in liver and hence it is safe in case of impaired renal function.

Spectrum:

Streptococcus and some forms of staphylococcus.

Not effective against most Gm –ve aerobic bacilli.

Administration:

Oral.

Adult dose 250 – 500 mg / 6 to 8 hours.

Could be increased up to 4gm /day, according to the severity of infection.

Adverse effects:

Mostly related to GI.tract such as nausea, vomiting, diarrhea, epigastric pain.

High, long doses cause transient deafness.

Allergy is extremely rare.

CLINDAMYCIN & LINCOMYCIN

Clindam -Lincocin - Dalacin - Cleocin

Antibacterujm spectrum is similar to erythromycin.

However, clindamycin has greater effect against anaerobes than erythromycin.

Administration :

Well absorbed orally.

Food does not decrease absorption.

Adult dose 150 300mg / 6 8 hours.

Adverse effects:

Nausea, vomiting, diarrhea, abdominal pain, urticaria, skin rash.

Major adverse effect is pseudomembranous colitis (fatal).

Pseudomembrane consists of fibrin, mucous, inflammatory cells, and

epithelial debris causing necrotizing inflammation of the bowl. This membrane covering the mucosa peels off causing bleeding and death.

TETRACYCLINES

Availability:

1. Tetracycline (Achromycin).
2. Oxytetracycline (Terramycin).
3. Chlortetracycline (Aureomycin).
4. Demeclocycline (Declomycin).
5. Doxycycline (Vibramycin).
6. Methacycline (Rondamycin).
7. Minocycline (Minocin, Vectrin)

Spectrum:

Bacteriostatic to gm+ve and gm-ve. staphylococcus and streptococcus bacteria. Neisseria, Actinomyces and Shigella.

Administration:

Orally, however they are incompletely absorbed from the GI tract.

Excreted in the bile, feaces and urine.

Adult dose 1 to 2 gm/ day divided into 2 to 4 doses.

Usually 250 to 500 mg.

Adverse effects:

The most directly toxic antibiotic.

Moderately allergenic.

Epigastric pain, nausea, vomiting, renal impairment, liver damage manifested as jaundice, acidosis and shock.

Staining of the developing dentition.

Contraindications:

Allergy

Liver damage

Renal failure

Tetracyclines are rarely the drug of choice for facial and dental infections.

METRONIDAZOLE(FLAGYL)

Bactericidal against obligate anaerobic microorganisms particularly bacteroides species.

Rapidly and completely absorbed from the GI. tract.

Administration:

Orally, rectally and IV.Injection.

Detoxified in liver and excreted in urine.

Adverse effects:

Nausea, headache, metallic taste and xerostomia.

As a result of its effect on DNA synthesis concerns have been raised regarding its mutagenic, teratogenic and carcinogenic potentials.

Therefore, we got to use it cautiously and avoid prescribing it for a long-term treatment.

Adult dose: 250-500mg / 6 to 8 hours.

CHAPTER REVIEW QUESTIONS

1. Compare aspirin with acetaminophen.
2. Discuss bacterial resistance to antibiotics.
3. Discuss nitrous oxide-oxygen pharmacosedation.
4. Compare penicillins with cephalosporins.
5. Describe allergenic reactions to penicillin.

REFERENCES

- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc ,2008.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.
- Ingle JI. Bakland LK. Endodontics. 4th ed. Williams & Wilkins. 1994.
- Morse DR. Clinical Endodontology. Charles C Thomas Publisher, 1974.
- Yagiela JA, Neidle EA, Dowel FJ. Pharmacology and Therapeutics for Dentistry. 4th ed. Mosby-year book, Inc, 1998.
- Seymour RA, Meechan JG, Yates MS. Pharmacology and Dental Therapeutics. 3rd ed. Oxford University Pres, 1999.
- Walton JG, Thompson JW, Seymour RA. Textbook of Dental Pharmacology and Therapeutics. 2nd ed. Oxford Medical Publications, 1994.
- Tripathi KD. Essentials of Pharmacology for Dentistry. Jaypee Brothers Medical Publishers (P) LTD, 2005.
- Weine FS. Endodontic Therapy. 5th ed. Mosby-Year book, Inc. 1996

23

Non surgical Endodontic Retreatment

Ghada El Hilaly Eid

Intended Learning objectives

After reading this chapter, the student should be able to

1. Describe differences between re-treatment and initial treatment.
2. Identify restrictive clinical conditions.
3. State indications for retreatment.
4. Describe nonsurgical treatment techniques.
5. Discuss considerations for case selection.

Chapter Outline

Unique considerations

Case Selection

Diagnosis

Selection of treatment

Treatment of existing disease

Prevention of disease .

Retreatment techniques

Access removal of root canal obturation materials and obstructions

Morphological alterations

Resistant infection

Short term and long term treatment outcome

Post-treatment disease associated with apical periodontitis is seen in more than 30% of root canal treated teeth.

It is primarily caused by infection of the root canal system. Microorganisms may either have survived previous treatment or invaded the filled canal space after treatment, mainly because of coronal leakage.

Less often, specific microorganisms may have established in the periradicular tissue; such as actinomyces.

The affected teeth can either be treated by nonsurgical retreatment (orthograde) or apical surgery (retrograde) or tooth extraction.

UNIQUE CONSIDERATIONS

Non surgical retreatment holds unique considerations that distinguish it from initial root canal treatment.

1. An extensive restoration may have to be removed.
2. Technical challenge from previous treatment may be presented as morphologic alteration in the form of perforation or ledge or canal obstructions by separated instruments.
3. Root filling must be removed from the canals.
4. Healing rate is generally slower than that of initial treatment because of the greater difficulty in eliminating resistant infection; E. faecalis, candida albicans

CASE SELECTION

Retreatment is usually performed to treat existing disease, presenting with definitive signs and symptoms. However, even in the absence of disease, retreatment may be indicated to prevent future emergence of disease.

DIAGNOSIS

The presence or absence of periradicular disease is determined according to clinical and radiographic findings. Differential diagnosis of nonendodontic disease is also considered.

Case history includes examination of previous radiographs, noting past symptoms, time elapsed since previous treatment (to avoid premature diagnosis of post-treatment disease), and previous attempts to retreat or perform apical surgery (may suggest vertical fracture).

SELECTION OF TREATMENT

TREATMENT OF EXISTING DISEASE

Comparing the two treatment modalities, nonsurgical retreatment offers greater benefit and smaller risk compared to apical surgery. It provides minimal invasion, and a lesser chance of injuring nerves, and sinuses. However, nonsurgical retreatment is not always possible, and the benefit-risk balance may not justify the preference of retreatment over surgery.

Considerations governing case selection in the management of post-treatment disease:

1- ***Patient considerations***: Patients' attitudes to dental disease and necessity to be treated differ. Moreover, *motivation* to retain every tooth and *pursue the best long-term outcome* may vary, as do ability to allocate, *time*, and *finance*.

2- ***Tooth considerations:*** When the patient indicates preference for retreatment, the tooth and surrounding structures are evaluated to identify clinical conditions that may adversely affect the prognosis.

- *Site of infection*: Root canal infection is best eliminated by retreatment. Extraradicular infection which is independent of root canal flora is best eliminated by apical surgery. While vertical root fracture (as indicated by isolated, narrow defect along the root) can not be eliminated with either procedure.
- *Root canal obstacles:* To eliminate root canal infection during retreatment, the canal must be renegotiated throughout. Obstacles to total renegotiation, such as calcifications, ledges, separated instruments, reduce the potential benefits of retreatment. Sometimes

attempts to overcome obstacles increase the risk of procedural complications as root perforation. Thus, the benefit-risk balance may change in favor to surgery.

- *Site of perforation:* Perforation of the pulp chamber or root canal can be a pathway of infection and worsen prognosis. Therefore, retreatment in conjugation with internal repair of the perforation is mandatory. When healing is not expected to occur external surgical repair of perforation may be required.
- *Restorative and periodontal factors:* Teeth considered having hopeless prognosis for either restoration or periodontal healing should be extracted. With compromised periodontal support, surgery may result in unfavorable crown-root ratio, retreatment is selected.

3- ***Clinician consideration:*** clinicians vary in their capability, availability of special armamentarium needed during retreatment, and the time that can be spent in retreatment. Endodontists are usually more capable, equipped to treat post treatment disease than general dentist.

4- ***Previous treatment attempts:*** If a previous retreatment or apical surgery procedure did not result in healing, the quality of the procedure should be evaluated. If the initial case selection was appropriate and the quality can be significantly improved, the same procedure is repeated. Otherwise the alternative is attempted which may better address the site of infection.

PREVENTION OF DISEASE

The emergence of post-treatment disease appears to be higher when both root filling and coronal seal are suspected, while a new restoration (post and crown and bridge) is needed. In these cases, retreatment is indicated because it offers the benefit of preventing post-treatment disease.

RETREATMENT TECHNIQUES

To perform retreatment, obstructions must be removed to fully renegotiate the canal. These include the coronal restoration, post and core and root filling materials. Sometimes, separated instruments and morphological alterations as well as resistant infection may have to be dealt with.

1: Access

Crowns

The crown may be retained if satisfactory, retreatment can be performed through the crown, rubber dam isolation and temporization are facilitated, function and esthetics are maintained, and additional cost of replacement is avoided. Access is prepared through the crown and repaired later.

OR

The crowns are removed if visibility is obscured and if crown margins are poorly adapted predisposing to leakage. Also, with the crown in place, the risk of irreparable errors during access is increased. For selected cases, the crown may be removed intact and reused later.

Post and core

Weakening Post retention:

The core is drilled away; leaving just the post exposed from the canal. The cement is then broken with ultrasonic vibration on the post for 10-20 min to loosen the post. Pointed tips are used to ultrasonically trough around the post, **Fig. (1).**

Post extraction by special devices

If the post can not be loosened by vibration, post removal system (PRS) can be used, where the post is bored with a trephine bur, firmly engaged with a matching size extractor. Special pliers are applied to the extractor using the tooth as a fulcrum.

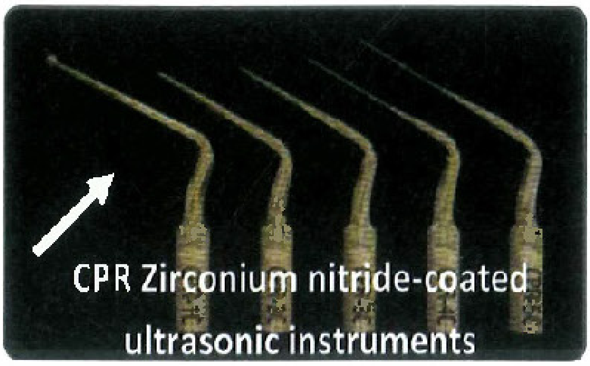


Fig 1. Ultrasonic tips

2: Removal of root canal obturation materials and obstructions:

Canal patency is regained by eliminating the root filling and occasionally separated instruments. To be successful, this procedure requires a straight line access. Previous access is evaluated; often it must be extended before elimination of root canal content.

Gutta-percha

Gutta-percha is removed with rotary instruments and hand files. Solvents are used selectively.

- *Rotary instruments*: In the coronal portion of the canal, Gates Glidden burs are used. They form reservoir for the solvent (if used) and improves access. Further apically nickel titanium retreatment rotary files or hand instruments can be used.
- *Solvents:* solvents soften gutta-percha and help prevent canal transportation. Therefore, it is used specifically for dense root fillings and in retreatment of curved canals. However, when gutta-percha cones are poorly condensed or overextended, solvent is avoided. Gutta-percha, and sealers are soluble to varying degrees in chloroform, halothane, benzene, xylene, and white rectified turpentine. Chloroform is the most effective but because of its toxicity, it must be used cautiously. Chloroform, if used, is dipped directly into the canal orifice, avoiding excessive flooding of the chamber. The operating team wears protective masks, and the patient's nose is covered with the rubber dam. Potential safer solvents include essential oils as eucalyptol and orange peel oil.
- *Hand files:* A reamer or file is used to negotiate a pathway along the root filling. H file of similar size is then carefully screwed into the filling mass and pulled back. The procedure of negotiation with K files and engaging with H files is repeated with larger sizes, often retrieving all the gutta-percha cones. With overextended cones, the file may have to be extended apically to avoid separation of the cones at the apical foramen. Overextended cones may separate at the apex and can not be retrieved.

Pastes and cements

- *Soft-setting pastes*: They may be penetrated by files using a crown down sequence.
- *Hard setting cements:* They should be initially exposed to solvents, if softened the cement is managed like the soft-setting paste. If not, the cement is broken down with ultrasonic vibration using special pointed tips. To prevent perforation, the procedure is frequently monitored with radiographs or operating microscope. As a last resort the cement is drilled out with long-shank, small round burs (Mueller burs).

Metallic objects

Metallic objects may often be retrieved or bypassed. Accessibility is more restricted from orifice level apically particularly in curved canals. Bypass is most feasible in oval canals.

- **Silver points**

If the silver point is extending into the pulp chamber, ultrasonic vibration frees silver point from cement, to be removed with Steiglitz pliers.

By pass: the canal is first flared with Gates Glidden bur, hand files with a lubricant or solvent to create a path around the metallic object. H file

is inserted in the space, engages the silver point and possibly pulls it out. If the object is bypassed but not retrieved, it will be enclosed in the root filling. The procedure may be complicated by additional file separation, perforation, or apical displacement of the object. Visualization is optimized with the operating microscope.

Extraction from the canal with special devices using *microtube removal option;* extracting mechanism includes end cutting trephines and extracting tubes with or without a locking mechanism.

* *The microtube tap-and-thread option:* The PRS contains small microtubular taps that allow the clinician to mechanically tap, thread, and engage any obstruction with 0.6 mm or greater. These microtubular taps contain a reverse thread and engage an obstruction by turning in counterclockwise motion, **Fig. (2)**.

* *The microtube mechanics option:* A microtube is selected to be placed over the exposed coronal-most aspect of obstruction. H file is then passed down the length of the tube until it engaged tightly between the obstruction and the internal lumen of the microtube. Pulling both, hopefully removes the obstruction.

- ***Separated instruments***

Ultrasonic vibration using special ultrasonic tips (longer and smaller profiles) in anticlockwise direction around the instrument to loosen, unwind and spin the separated instruments out of the canal.

By pass: preflaring with Gates Glidden drills, hand files with a lubricant create a path around the instrument, and the object is included in the filling.

Extraction from the canal: on occasion, the clinician may create excellent coronal and radicular access, identify and expose the separated instrument, and still unable to loosen the instrument out of the canal. A ***microtube device*** as ***Instrument Removal System (IRS)*** can be used, to engage and potentially remove it mechanically. A trough is cut around the object with ultrasonic tips or trephines; matching extractor tube is applied, locked and withdrawn.

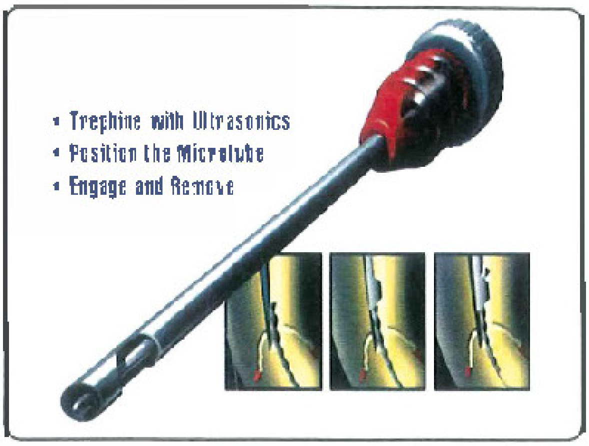


Fig. 2. Microtube device for post and separated instrument removal

Because extraction procedure requires considerable sacrifice of root dentin, it is thus safe only in large straight roots.

If the object is not bypassed or retrieved, only the accessible portion of the canal is re-treated. Prognosis is better when there is no root canal infection and periradicular disease.

3: Morphological alteration

For locating and negotiating missed (extra) canals and management of blocks, ledges, apical canal transportations and endodontic perforations, see chapter of endodontic mishaps.

4: Resistant infection after rengotiating the canal, treatment is complete using routine procedures. However, elimination of root canal infection is more challenging than in initial treatment, primarily because there may be therapy resistant microorganisms such as faecalis (facultative anaerobes). Also microorganisms may persist under residual root filling patches which usually remain during treatment. Finally canal surfaces may remain untouched during retreatment.

The following may thus be recommended for the management of post treatment disease:

- A wide direct access, with canal enlargement beyond its previous size to reduce residues of filling materials. Frequent irrigation with effective disinfectant solutions such as sodium hypochlorite NaOCl 5.25% and chlorhexdine 2% .
- Calcium hydroxide is used as intracanal medication for canal disinfection; therefore two or more visits are required.

SHORT-TERM AND LONG-TERM TREATMENT OUTCOMES

In the short term, retreatment with existing post-treatment disease may be associated with postoperative discomfort, including pain and swelling. This is an additional reason why retreatment for existing disease should not be completed in one visit.

The long term outcome of retreatment depends largely on the regaining canal patency. The probability of healing is higher when factors facilitating infection (untreated or poorly treated canals) are identified and managed during retreatment.

CHAPTER REVIEW QUESTIONS

1. State the indications of retreatment.
2. Enumerate unique considerations related to retreatment as compared to initial treatment.
3. Describe factors affecting case selection in retreatment
4. Describe retreatment techniques for gutta percha removal.
5. Describe retreatment techniques for removal of canal obstructions as post and core or separated instruments.

REFERENCES

- Theodor Lambrianidis. Management of Fractured Endodontic Instruments A Clinical Guide. Springer International Publishing AG 2018
- Cohen S, Burns R C. Pathways of the pulp 8th ed Mosby, 2016
- Walton RE, Torabinejad M. Principles and practice of Endodontics. 3rd ed W.B. Saunders company, 2015
- Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics 6, BC Decker Inc. 6th edition 2008
- Ruddle CJ: Nonsurgical retreatment, J Endod 30:827, 2004.
- Paik S, Sechrist C, Torabinejad M: Levels of evidence for the outcome of endodontic retreatment, J Endod 30:745, 2004.
- de Chevigny C, Dao TT, Basrani BR, et al: Treatment outcome in endodontics—the Toronto study, phases 3 and 4: orthograde retreatment, J Endod 34:131, 2008.
- Torabinejad M, Corr R, Handysides R, et al: Outcomes of nonsurgical retreatment and endodontic surgery: a systematic review, J Endod 35:930, 2009.

24

Evaluation of Success and Failure

Ghada El Hilaly Eid

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define a successful and unsuccessful root canal treatment
2. Describe the factors that influence the prognosis (outcome) of the treatment
3. Describe the methods of determining success or failure
4. Correlate causes of endodontic failure with prognosis before, during & after treatment

Chapter Outline

What is Success?

Success of endodontic treatment of vital *diseased pulp* means that the root canal treatment prevents bacteria from entering the root canal system; thereby; the treatment prevents periradicular lesion from forming. *With necrotic pulp*, the treatment is considered successful if it eliminates or significantly reduces bacteria in the root canal system so that an associated periradicular lesion heals. *Prognosis* is the prediction of whether an endodontic treatment will prevent the development of apical periodontitis or heal if present.

Unfortunately, not all root canal treatments are successful.The clinician should attempt to predict the outcome of each treatment based on existing knowledge and *inform the patient* about the expected outcome. Prediction of the outcome should be done at three times: *before, during and after treatment*. The prognosis often changes at these intervals, depending on what occurs or what is discovered during or after treatment.

Factors Influencing Success and Failure

Reported *success rates* range from a high of 95% to a low of 53%, various factors were analyzed in relation to success and failure. Some of the factors that consistently impact prognosis are:

1. *Presence of periradicular lesion* associated with the tooth before treatment, which may reduce success by 10% to 20%.
2. *Bacteria status* of the canal. The presence of bacteria in the canal before obturation predicts a poorer prognosis.
3. The technical quality of *root canal preparation*.
4. Extent and quality of *obturation*. In relation to extension of obturation, healing is less predictable if the filling is too short (more than 2mm from the radiographic apex)or too long (extending from the apex). More voids and or less density of the obturating material is also related to lower success rates.
5. The *quality of coronal restoration and the effectiveness of coronal seal*. With a poor coronal seal most treatments will eventually fail irrespective of the periradicular status of the tooth before treatment or the quality of debridment and obturation.

When to Evaluate?

Suggested postoperative follow-up periods range from *6 months to 4 years*; 6 months is a reasonable interval for recall evaluation for most patients.

Unfortunately, apparent success may revert to failure at a later time(often as a result of coronal leakage), so clinical and radiographic examinations of teeth treated with root canals are indicated as part of routine full-status evaluation of all dental procedures.

Methods of Evaluation

With current technology, practical means of determination of healing or nonhealing are based on clinical findings (signs and symptoms) and radiographic evaluation.

Clinical examination: Persistence of adverse significant signs (e.g. swelling or sinus tract) or symptoms (e.g. spontaneous pain, dull persistent ache, or mastication sensitivity) indicates failure. Importantly, absence of pain or other symptoms doesn't confirm success. This is because periradicular pathosis without significant symptoms is usually present in teeth before as well as after root canal treatment.

Radiographic findings: according to the findings, the outcome of each treatment could be classified as a success, failure, or questionable status. *Success is evident by* the elimination or non development of an area of apical radiolucency for a minimum of 1 year after treatment. *Failure is evident* by enlargement or development of radiolucent lesion since treatment. *Questionable*

status indicates a state of uncertainty, when a radiolucent lesion has neither become larger nor significantly decreased in size, with a possibility of healing by fibrous rather than bony tissue. Complete radiographic regeneration of periradicular structures does not always occur, but can be still defined as healed There may be unusual trabecular pattern or lack of complete replacement of the cortical plate adjacent to the tooth, giving the appearance of persistent lesion.

To be able to accurately compare radiographs made at different times, it is important that they are taken in a reproducible fashion and with minimal distortion as achieved with the use of paralleling radiographic devices for periapical radiographs or better use the cone beam computed tomography (CBCT).

Causes of Endodontic Failures

Most nonhealing root canal treatments are directly or indirectly caused by *bacteria* somewhere in the root canal system.Any*mishap* (refer to chapter of mishaps) occurring during the procedures associated with root canal treatment can predispose to failure. Generally, root canal treatment failure can occur during any of the three phases: *preoperative, operative, and postoperative*.

Preoperative Causes: some of the preoperative considerations include; misdiagnosis, errors in treatment planning, poor case selection, or treatment of a tooth with poor prognosis.

Forming a correct diagnosis of the pulpal and periradicular status is based on all available information; clinical and radiographic evaluations. Otherwise there is a risk of inappropriate treatment and/or wrong tooth being treated.Extra canals can be diagnosed using radiographic projection with different horizontal angulation. Vertical root fracture must be considered, if an isolated deep periodontal defect is associated with a suspected tooth.

Operative Causes: these include both *mechanical and biological* causes.

1- Mechanical causes: for predictable success, several steps need to be followed during access cavity preparation, root canal instrumentation and obturation.

a A *straight line access preparation* facilitates debridment and obturation. If the access is *underextended* several mishaps may occur that ultimately lead to failure, a canal may be missed, improper deroofing may cause the pulp horn to retain debris and sealer with ultimate discoloration, additionally insufficient cleaning and shaping or even instrument breakage may occur. Overextended access cavities, prepared at the expense of dentin, weakens the tooth, possibly allowing fractures and increases risk of perforation.

b- During *instrumentation* a common error is failure to maintain canal curvature because files cut to the outside of the curve (transportation). This alters canal morphology and leaves infected debris in the canal system. Excessive preparation in the "danger zone" orin the apical 1/3 may result in strip perforation or apical perforation, respectively. These perforations are possible to repair but may require surgical intervention. Leakage and/or mechanical irritation may result and a lesion may develop.

The outcome of separated instrument (broken) in a root canal system depends on the stage of canal preparation, pretreatment pulp status (vital versus necrotic) and the level at which the instrument separated. The outcome may be unaffected if the instrument can be removed or bypassed. Overinstrumentation causes some tissue damage, and may also transfer microorganisms from the canal to the periapex, possibly compromising the outcome.

c- *Errors in obturation* may result from poor canal shaping or selecting inappropriate obturating technique. Overextended

obturation may lead to failure, possibly because the combination of an inadequate seal was preceded by overinstrumentation. A poorly condensed obturation can cause apical and/or coronal percolation. Either under obturation or overfilling is likely to result in failure, particularly in the presence of pulp necrosis and an apical lesion.

2- ***Biological Causes***: Ideally after preparation, the root canal would be free of bacteria. With a vital diseased pulp this means prevention of contamination and with a necrotic pulp, means achieving disinfection. Bacterial counts are minimized by careful instrumentation, copious NaOCl irrigation, and intracanal medication as calcium hydroxide.

Postoperative Causes:

Coronal restoration protects and seals the tooth, preventing diffusion of saliva and bacteria apically. There should be no space between the coronal filling and obturation in the cervical area. There is a correlation between poorly restored crowns of endodontically treated teeth and leakage of bacteria or endotoxin through the canals and poorer prognosis. Restorative errors also may compromise success, for example, excessive dentin removal for posts weakens the root and increases susceptibility of fracture.

CHAPTER REVIEW QUESTIONS

1. Define success of endodontic treatment.
2. Define prognosis of endodontic treatment.
3. List factors that influence success and failure.
4. Describe methods of evaluating success and failure.
5. Describe preoperative, operative and post operative causes of endodontic failures.

REFERENCES

- Nadia Chugal , Louis M. Lin. Endodontic Prognosis Clinical Guide for Optimal Treatment Outcome. Springer International Publishing Switzerland 2017
- Cohen S , Burns R C . Pathways of the pulp 8th ed Mosby, 2016
- Walton RE, Torabinejad M Principles and practice of Endodontics. 3rd ed W.B. Saunders company, 2015
- Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics 6, BC Decker Inc, 6th edition 2008
- de Chevigny C, Dao TT, Basrani BR, et al: Treatment outcome in endodontics—the Toronto study, phase 4: initial treatment, J Endod 34:258, 2008.
- Torabinejad M, Kutsenko D, Machnick TK, et al: Levels of evidence for the outcome of nonsurgical endodontic treatment, J Endod 31:637, 2005.
- Friedman S, Abitbol S, Lawrence HP: Treatment outcome in endodontics: the Toronto Study—phase I: initial treatment, J Endod 29:787, 2003.
- Seltzer S: Long-term radiographic and histological observations of endodontically treated teeth, J Endod 25:818, 1999.

25

Evaluation of Outcomes

Shaimaa I. Gawdat
Sherif A. Elkodary

Intended Learning objectives

After reading this chapter, the student should be able to

1. Know the surrogate outcome measures
2. List the types of outcome measures
3. Know the purpose of evaluating outcomes
4. Know the outcome measures of endodontic treatment, vital pulp therapy, non-surgical root canal treatment, non-surgical retreatment and surgical retreatment.

Chapter Outline

Types of disease and their treatment

Surrogate outcome measures

Types of outcome measures

Purpose of evaluating outcomes

1. Effectiveness of procedures
2. Factors affecting outcomes
3. Value for prognostication

Outcome measures for endodontic treatment

1. Outcome measures for vital pulp therapy procedures
2. Outcome measures for nonsurgical root canal treatment and retreatment
3. Outcome measures for periapical surgery

Outcomes of vital pulp therapy procedures

1. Indirect pulp capping (One-Step versus Stepwise Excavation)
2. Direct pulp capping
3. Pulpotomy

Outcomes of nonsurgical root canal treatment

Factors affecting periapical health or healing following root canal treatment

1. Patient factors
2. Treatment factors
3. Post root canal treatment restorative factors

Outcomes of nonsurgical retreatment

Outcomes of surgical retreatment

EVALUATION OF OUTCOMES

Types of Disease and Their Treatment

Endodontic treatment encompasses the following procedures:

1. Vital pulp therapy (indirect pulp therapy, direct pulp capping, pulpotomy, regenerative pulp therapy)
2. Nonsurgical root canal treatment
3. Nonsurgical root canal retreatment
4. Surgical retreatment

   The ideal outcome for endodontic treatment consists of controlled reduction of inflammation, accompanied by healing through regeneration, although sometimes repair may follow instead.

WHAT ARE SURROGATE OUTCOME MEASURES?

Signs of acute inflammation are classically described in the "triple response" exhibited by

1. Mechanically injured skin, which includes altered color (redness),
2. Texture/contour (swelling)
3. Sensation (pain), which are directly accessible and viewable.

Chronic inflammation does not necessarily exhibit the same highly visible signs and symptoms of its histopathologic character. The clinician is therefore left with indirect or associated changes by which to judge the presence or absence of disease; these are called "surrogate" measures.

Types of Outcome Measures

The prepared shape of the root canal system, bacterial load reduction, and technical quality of the root filling may all be regarded as outcome measures.

The ultimate *clinical* measure of a treatment outcome is assessing the prevention and resolution of disease.

The outcome of endodontic treatment may be assessed in four dimensions:

1. Physical/physiologic and related to presence or absence of pulpal/periapical health/disease, pain, and function.
2. Assesses longevity or tooth survival.
3. Relates to economics and assesses direct and indirect costs.
4. Examines psychologic aspects involving perceptions of oral health–related quality of life (OHRQoL) and aesthetics.

WHAT IS THE PURPOSE OF EVALUATING OUTCOMES?

1- Effectiveness of Procedures:

First, treatment procedures must be effective. Otherwise, there is no reason to recommend them.

The patient must be properly informed as to the risks, benefits and potential outcomes of the offered treatment.

If the clinician is uncertain of a result or feels that the outcome could be enhanced by treatment from another clinician, then referral to someone else more qualified is paramount.

2- Factors Affecting Outcomes:

Pooling data offers the potential to evaluate and prioritize the factors that exert a dominant influence on outcomes. In this way, protocols for treatment may be improved.

3- Value for Prognostication:

Prognostication, which could be defined as the prediction, projection, prophesizing, or foretelling the likely outcome of treatment.

The overall prognosis of a tooth depends on the interaction among three individual and often independent variables, including endodontic, periodontal, and restorative prognoses.

OUTCOME MEASURES FOR ENDODONTIC TREATMENT

1- Outcome Measures for Vital Pulp Therapy Procedures:

Vital pulp therapy include:

1. Indirect pulp capping with one-step or step-wise caries excavation.
2. Direct pulp capping of exposed pulps.
3. Partial/full pulpotomy procedures for more extensively involved pulps.

The surrogate outcome measures adopted in studies include:

1. Clinical success (pulp sensitivity to cold test and absence of pain, soft-tissue swelling, sinus tract, periradicular radiolucency, or pathologic root resorption),
2. Patient satisfaction.
3. Adverse events (pain, swelling, tooth fracture).
4. Tooth extraction

The European Society of Endodontology suggests "initial review at no longer than 6 months and thereafter at further regular intervals". (table 1)

Criteria for Assessing the Outcome of Pulp Therapy

Quality Guidelines for Endodontic Treatment: Consensus Report of the European Society of Endodontology (2006)	Guidelines on Pulp Therapy for Primary and Immature Permanent Teeth (The American Academy of Paediatric Dentistry 2014)
1. Normal response to pulp sensitivity tests (when feasible)	1. Tooth vitality maintained
2. Absence of pain and other symptoms	2. Absence of posttreatment signs or symptoms such as sensitivity, pain, or swelling
3. Radiologic evidence of dentinal bridge formation	3. Occurrence of pulp healing and reparative dentin formation
4. Radiologic evidence of continued root formation in immature teeth	4. Absence of radiographic evidence of internal or external root resorption, periapical radiolucency, abnormal calcification, or other pathologic changes
5. Absence of clinical and radiographic signs of internal root resorption and apical periodontitis	5. Teeth with immature roots should show continued root development and apexogenesis

An initial assessment at 6 to 12 weeks, followed by a review 6 and 12 months after treatment, seems to have been accepted and is recommended.

2- Outcome Measures for Nonsurgical Root Canal Treatment and Retreatment:

The pulp is irreversibly inflamed, necrotic, or infected to the extent that vital pulp therapy would not resolve the problem, which therefore requires pulpectomy (effective and aseptic removal of the pulp tissue regardless of the clinical protocol used).

Once periapical lesion develops, the challenge is a different one because the purpose now is to remove the bacterial biofilm and effect switching-off the periapical host response.

Ideal healing would eventually result in regeneration and the formation of cementum over the apical termini, isolating the root canal system from the periapex.

The outcome measures for healed periapical disease are:

1. Absence of pain, tenderness to pressure/percussion of the tooth, tenderness to palpation of the related soft tissues
2. Absence of swelling and sinus tract
3. Radiographic demonstration of reduction in the size of the periapical lesion (if sufficient time has lapsed).

NB Although the majority of periapical lesions heal within 1 year, healing may continue for up to 4 years or longer.

NB Radiographic evidence of a persistent periapical radiolucency may indicate either fibrous repair or persistent chronic inflammation or infection.

The periapical status of root-treated teeth has traditionally been assessed using two-dimensional conventional radiographic imaging.

Digital imaging technology brought the possibility of image manipulation, including digital subtraction, densitometric analysis, correction of grey values and the manipulation of brightness and contrast.

Cone-beam computed tomography (CBCT), a new three dimensional imaging technique overcoming the problem of superimposition of tissue layers and structures.

3- Outcome Measures for Periapical Surgery:

Nonsurgical root canal treatment alone may fail to resolve apical periodontitis in a small proportion of cases because it may not allow access to the infection.

In these instances, a surgical approach to the periapex may be required in addition to the nonsurgical approach.

The success of periapical surgery has been assessed with the same clinical and radiographic criteria as for nonsurgical root canal treatment.

Periodontal attachment loss in the form of marginal gingival recession is an additional criterion for measuring the outcome of periapical surgery.

OUTCOMES OF VITAL PULP THERAPY PROCEDURES

1- Indirect Pulp Capping (One-Step versus Stepwise Excavation):

The stepwise excavation approach with initial partial caries removal was advocated to reduce the risk of pulpal exposure and is generally considered to be associated with poorer outcomes.

However, in three randomized controlled trials on permanent teeth with deep caries, stepwise excavation was found to be associated with a lower rate of pulp exposure and higher chance of long-term clinical success than the one-step excavation approach.

The type of lining material did not influence the outcome.

The age of patients, presence of preoperative pain, and pulpal exposure during excavation were significant negative prognostic factors.

2- Direct Pulp Capping:

Direct pulp capping is performed on teeth with pulp exposures.

Saline, sodium hypochlorite, and chlorhexidine have been reportedly used to irrigate the exposed pulp and to achieve hemostasis. Calcium hydroxide paste and mineral trioxide aggregate (MTA) were the commonly used capping materials showing 70.1% success rate.

The patient's age and sex, tooth location and type, pulp exposure type, size, and its location and the restoration type, size, and quality did not have a significant influence on success.

Teeth with immature roots were associated with significantly more successful outcomes.

The type of capping material was another significant prognostic factor, with MTA performing superiorly to calcium hydroxide.

3- Pulpotomy:

The success rate for partial pulpotomies is 79.3% while for full pulpotomies is 82.4%.

Randomized controlled trials revealed that MTA achieved similar outcomes in partial or full pulpotomies when compared with calcium hydroxide.

Summary of Prognostic Factors for Vital Pulp Therapy:

The most important factors affecting the outcome of vital pulp therapy are:

a. Preexisting health of the pulp.

b. Adequate removal of infected hard or soft tissues.

c. Careful operative technique to avoid damage to residual tissues.

d. Elimination of microbial leakage around the final restoration.

NB. The degree of pulp bleeding upon exposure is a more reliable tool to judge the status of the pulp than the preoperative clinical signs and symptoms.

OUTCOMES OF NONSURGICAL ROOT CANAL TREATMENT

Factors Affecting Periapical Health or Healing Following Root Canal Treatment:

1- Patient Factors:

a) Patient's age and sex:

They had no significant effect on outcome, whereas some specific health conditions (diabetes, compromised immune response) apparently had a significant influence.

b) Tooth anatomy:

The widespread perception that single rooted teeth with less complicated anatomy should benefit with more predictable and favourable outcomes proves to be untrue.

Canal complexities in the apical anatomy probably play a more dominant role than other complexities such as the number and curvature of canals.

c) Preoperative pulpal and periapical status:

The presence and size of a periapical lesion seem to have the most negative effect on periapical health/healing.

This is attributed to the diversity of bacteria that may have penetrated deeper into dentinal tubules and accessory anatomy in the complex canal system where mechanical and chemical decontamination procedures may not be so effective.

The presence of preoperative pain, sinus tract, swelling and apical resorption have been found to be significant prognostic factors that have been associated with significantly reduced success rates in root canal treatment.

2- Treatment Factors:

a) Operator:

Clearly technical skills play an important role in prognosis.

b) Isolation:

The use of rubber dams showed significantly higher success rates when compared to cotton roll isolation.

c) Magnification and Illumination:

Researchers found only an insignificant influence on the final outcome.

Use of a microscope may sometimes assist location of the second mesiobuccal canal in maxillary molars, but this only made a small difference to the success rates.

d) Mechanical Preparation: Size, Taper, Extent and Procedural Errors:

1) Size:

Enlargement of the canal to three sizes larger than the first apical binding file was adequate.

Canal preparation to larger apical sizes may compromise treatment success by generation of more apical dentine debris, which in the absence of an adequate irrigation regimen serves to block apical canal exits that may still be contaminated with bacteria.

2) Taper:

The ESE guidelines recommend only that canal preparation should be tapered from crown to apex without stipulating any particular degree of taper.

There was no significant difference in treatment outcome between narrow (.05) and wide (.10) canal tapers.

3) Extent:

The European Society of Endodontology (ESE) guidelines is that root canal debridement must be extended to the terminus of the canal system, which is expressed variously as extension to the apical constriction, or 0.5 to 2 mm from the radiographic apex or to the cementodentinal junction.

4) Procedural errors:

This include *canal blockage, ledge formation, apical zipping and transportation, straightening of canal curvature, tooth or root perforation at the pulp chamber or radicular level* and *separation of instruments.*

Instrument separation during treatment has been found to reduce the success rates significantly.

The stage of canal debridement at which instrument separation occurred and the justification for their retention may have implications on the outcome.

The coronoapical location of a separated instrument and whether the instrument was successfully bypassed were found to have no effect on treatment outcome.

e) Irrigant:

ESE recommends a solution possessing disinfectant and tissue dissolving properties.

1) Sodium hypochlorite:

A higher concentration of sodium hypochlorite made negligible difference to treatment outcome.

2) Chlorhexidine:

The use of chlorhexidine as a final irrigant following sodium hypochlorite irrigation had been recommended this is due to its substantivity in root dentin (i.e., prolonged antibacterial effect), relative lack of toxicity and broad spectrum efficacy.

The alternate irrigation with sodium hypochlorite and chlorhexidine solution produced an insoluble precipitate containing para-chloroaniline, which is cytotoxic and carcinogenic.

3) EDTA:

EDTA had a profound effect on improving radiographically observed periapical healing associated with root canal treatment this is due to deeper penetration of irrigant into dentine by opening dentinal tubules and removing the smear layer.

f) Medicament:

The use of a mixture of calcium hydroxide and chlorhexidine has been tested based on the speculation that the mixture would be more effective against *E. faecalis.*

g) Root canal bacterial culture results prior to obturation:

In the past, obturation would only be acceptable after a negative culture test was obtained.

This practice has fallen out of clinical favour because of :

i) The good prognosis of root canal treatment without microbiologic sampling.

ii) The procedure is lengthy, difficult and often inaccurate requiring laboratory support.

The outcome is even worse when a positive culture test result combines with the presence of a periapical lesion.

h) Effect of persistent bacteria on root canal treatment outcome:

The bacteria present in preobturation cultures have included *Enterococcus, Streptococcus, Staphylococcus, Lactobacillus, Veillonella, Pseudomonas, Fusobacterium* species and yeasts.

The overall failure rate for cases with positive cultures was 31%.

Teeth testing positive for *Enterococcus* species had a failure rate of 55%, and teeth with positive

cultures for *Streptococcus* species had 90% failures.

The success rate for teeth with no bacteria was 80%, whereas that for teeth with bacteria in the canal before obturation was 33%.

i) Root filling material and technique:

There is no evidence to show that the nature of root filling material and the technique used for placement has any significant influence on treatment outcome.

j) Apical extent of root filling:

The apical extent of root fillings has been classified into three categories for statistical analyses:

- More than 2 mm short of radiographic apex (short)

- 0 to 2 mm within the radiographic apex (flush)

- Extended beyond the radiographic apex (long)

Flush root fillings were associated with the highest success rates, whereas long root fillings were associated with the lowest success rates.

k) Quality of root filling:

An unsatisfactory root filling has been defined as *inadequate seal* (poor apical seal) or *radiographic presence of voids* were found to be associated with significantly lower success rates than satisfactory root fillings.

l) Acute exacerbation during treatment:

The presence of pain or swelling in cases after chemomechanical debridement was found to significantly reduce success as measured by periapical healing.

Flare-ups were caused by:

Extrusion of contaminated material during canal preparation.

- Incomplete chemomechanical debridement at the first appointment, leading to a shift in canal microbial ecology favouring the growth of more virulent microorganisms.

m) Number of treatment visits:

The number of treatment visits for completing root canal treatment and their effect on periapical healing remains an ongoing controversy.

The premise for multiple-visit treatments has been that primary debridement is not completely effective in eliminating all the adherent bacterial biofilm and the residual bacteria may multiply and recolonize the canal system.

Calcium hydroxide used as interappointment dressing has ability to:

- Dissolve organic tissue

Kill bacteria

- Detoxify antigenic material

3- Post Root Canal Treatment Restorative Factors:

a) Effect of Quality and Type of Restoration:

Teeth with satisfactory coronal restorations were found to have significantly better periapical healing compared with those with unsatisfactory restorations.

Satisfactory restorations has been defined as a restoration with no evidence of

(1) Marginal discrepancy

(2) Discoloration

(3) Recurrent caries with absence of a history of decementation.

Unsatisfactory restorations were defined as those with:

(1) Obvious signs of exposed root filling

(2) Potential leakage indicated by marginal defects and history of de-cementation.

b) Use of root treated teeth as abutments for prostheses and occlusal contacts:

It is reasonable to expect that bridge and denture abutments may be placed under unfavorable loads which may therefore be expected to have lower success rates because of a potential

increase in the development of cracks and fractures due to fatigue.

Summary of Factors Influencing Periapical Healing Following Nonsurgical Root Canal Treatment:

1. Presence and size of periapical lesion.
2. Patency at the canal terminus (achieving patency significantly increased the chance of success).
3. Apical extent of chemomechanical prepara tion in relation to the radiographic apex.
4. Outcome of intraoperative culture test.
5. Iatrogenic perforation (if present, reduces the odds of success by 30%).
6. Quality of root canal treatment judged by the radiographic appearance of the root filling.
7. Quality of the final coronal restoration.

The following factors are considered as having minimal impact on root canal treatment outcome:

1. Age of patient.
2. Gender of patient.
3. Tooth morphologic type.
4. Specific root canal treatment protocol and technique (preparation, irrigation, and obturation material and technique).

Factors Affecting Tooth Survival Following Root Canal Treatment:

A systematic review and meta-analysis has shown that 93% of endodontically treated teeth survive at 2 years postoperatively but this survival reduced to 88% at 10 years following treatment, this is due to due to problems of endodontic origin, tooth/root fracture, or restoration failure.

1- Patient Factors:

Patients suffering from diabetes or receiving systemic steroid therapy had a higher chance of tooth extracted after root canal treatment.

Diabetic patients are more susceptible to periodontal disease or have a lower success rate of root canal treatment because of being immunologically compromised.

2- Tooth Morphologic Type and Location:

Maxillary premolars and mandibular molars were found to have the highest frequency of extraction, with tooth fracture being the most common reason.

3- Preoperative Conditions of Teeth:

The presence of preoperative periapical lesions, which is the most significant prognostic factor for periapical healing, was found to have no significant influence on tooth survival.

The presence of preoperative periodontal probing defects of endodontic origin, preoperative pain and preoperative sinus tracts were found to reduce tooth survival.

The presence of preoperative cervical resorption and perforation was also found to significantly reduce tooth survival.

4- Treatment Factors:

Lack of patency at apical foramen and the extrusion of gutta-percha root filling were found to be the most significant intraoperative factors in reducing tooth survival.

Summary of Factors Influencing the Survival of Teeth Following Root Canal Treatment:

The following conditions have been found to significantly improve tooth survival following root canal treatment:

1. Non molar teeth.
2. Teeth with both mesial and distal adjacent teeth.
3. Teeth not located as the distal-most tooth in the arch.
4. Teeth (molar) with cast restorations after treatment.

5. Teeth not requiring cast post and core for support and retention of restoration.
6. Teeth not functioning as abutments for fixed prosthesis.
7. Absence of preoperative deep periodontal probing defects, pain, sinus tract, or perforation.
8. Achievement of patency at canal terminus and absence of root-filling extrusion during treatment.

OUTCOME OF NONSURGICAL RETREATMENT:

The periapical healing rates of root canal retreatment are generally perceived to be lower compared to primary treatment for the following reasons:

1- Obstructed access to the apical infection.

2- A potentially more resistant microbiota.

The most significant factor influencing the outcome of treatment is the ability to remove or bypass pre-existing root-filling material or separated instruments during retreatment.

OUTCOME OF SURGICAL RETREATMENT:

Factors Affecting Periapical Health or Healing Following Periapical Surgery and Root-End Filling:

The factors having a major impact on outcome of periapical surgery with retrograde cavities and fillings in teeth with preoperative periapical radiolucencies are:

1. Small ($\leq$ 5 mm) versus large (> 5 mm) periapical lesion.
2. Periapical lesion involving one versus both cortical plates.
3. Absence versus presence of previous surgery.
4. Using magnification versus without the use of magnification during surgery.
5. Root-end resection with minimum versus obvious bevel.
6. Use of ultrasonic tip versus bur for retro-cavity preparation.
7. Use of retro-filling material with mineral trioxide aggregate (MTA) cement, super ethoxybenzoic acid (EBA) cement, or intermediate restorative material (IRM) versus amalgam; the use of MTA resulted in a similar outcome to Super EBA or IRM. Super EBA and IRM were associated with significantly higher chances of success than amalgam.
8. The preoperative presence of signs or symptoms, periodontal status and quality of the coronal restoration.

The following factors have minimal effect on surgical retreatment:

1. Age of patient.
2. Gender of patient.
3. General health of patient.
4. Tooth type.
5. Quality of the pre-existing root canal filling, as judged radiographically.
6. Histologic diagnosis of the biopsied periapical lesion (cyst or granuloma).

Factors Affecting Periodontal Incisional Wound Healing:

All concluded that negligible marginal recession could be achieved by adopting a flap design that avoided reflection of the interproximal papilla.

Factors Affecting Tooth Survival Following Periapical Surgery and Root-End Filling:

The survival time for first-time surgery was 92.1 months and that for resurgery was 39.1 months.

CHAPTER REVIEW QUESTIONS

1. What are surrogate outcome measures?
2. List the types of outcome measures.
3. What are the purposes of evaluating outcomes?
4. List the outcome measures of endodontic treatment, vital pulp therapy, non-surgical root canal treatment, non-surgical retreatment and surgical retreatment

REFERENCES

- Hargreaves KM, Cohen's Pathways of the Pulp.11th ed. Mosby El Sevier, 2016.
- Bjorndal L, Reit C, Bruun G, et al: Treatment of deep caries lesions in adults: randomized clinical trials comparingstepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy, *Eur J Oral Sci* 118:290, 2010.
- Maltz M, Garcia R, Jardim JJ, et al: Randomized trial of partial vs. stepwise caries removal: 3-year follow-up, *J Dent Res* 91:10261, 2012.
- Maltz M, Henz SL, de Oliveira EF, Jardim JJ: Conventional caries removal and sealed caries in permanent teeth: a microbiological evaluation, *J Dent* 40:776, 2012.
- El-Meligy OA, Avery DR: Comparison of mineral trioxide aggregate and calcium hydroxide as pulpotomy agents in young permanent teeth (apexogenesis), *Pediatr Dent* 28:399, 2006.
- Qudeimat MA, Barrieshi-Nusair KM, Owais AI: Calcium hydroxide vs mineral trioxide aggregates for partial pulpotomy of permanent molars with deep caries, *Eur Arch Paediatr Dent* 8:99, 2007.

4
PART

RELATED ENDODONTIC TOPICS

26 Tissue Engineering In Endodontics

Jealan M. El Shafei

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define tissue engineering and regenerative endodontics.
2. Describe the three key ingredients for tissue engineering (morphogenes, scafolds and stem cells).
3. Describe human dental pulp stem cells with their properties and functions.
4. Define gene therapy and describe its types (in vivo and ex vivo).
5. Describe vectors.
6. Describe new concepts of regenerative endodontics in management of immature permanent teeth.
7. Describe natural irrigants and their role in regenerative endodontics.

Chapter Outline

DEFINITIONS

Tissue engineering is the three-dimensional assembly over time of vital tissues and organs by a process involving cells, signals and extra cellular matrix.

Is the science of design and manufacturer of new tissue to replace lost one by diseases such as cancer, trauma or even caries.

Is the field of functional restoration of tissue structure and physiology for impaired or damaged tissues because of cancer, diseases and trauma.

Regenerative endodontics is the creation and delivery of tissues to replace diseased, missing, and traumatized pulp.

Endodontic treatment consisting of the removal of the entire pulp and replacing it with gutta-percha (rubber like material). There have been no other effective ways to repair the infected or injured pulp tissue besides complete amputation. Removing the entire pulp poses two clinical problems :

- ***Further dental work such as crown and post that weaken the tooth are most often required.***
- ***Devitalized immature teeth are weak with little dentin structure.***

Recent advances in pulp stem cell isolation and tissue engineering technologies have shed light on the possibility of pulp tissue regeneration.

Tissue engineering with the triad of dental pulp progenitor/stem cells, morphogens, and scaffolds may provide a *useful alternative method for pulp capping and root canal treatment.*

The three key ingredients for tissue engineering are 3S

- Signals for morphogenesis (bone morphogenic protein BMP or BMP gene) including growth and differentiation factors
- Stem cells or progenitor cells to respond to morphogenesis
- Scaffold of extra cellular matrix

MORPHOGENS

DEFINITION

Are biological factors that regulate stem cells to form the desirable cell type .

Are inductive signals that function as growth/differentiation factors in odontoblast differentiation.

Bone morphogenic proteins (BMPs) are multi-functional cytokines widely distributed both in skeletal and non-skeletal tissues. They have a major role in organogenesis BMPs also play a role in differentiation of dentin in teeth.

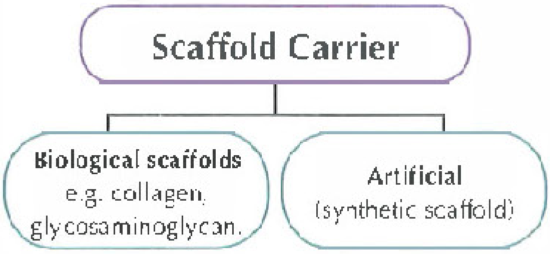
The recent progress in molecular developmental biology permits the delivery of BMPs by gene therapy.

SCAFFOLD CARRIER

Is a biodegradable matrix which is required for ease of delivery of cells to the wound site as well as to provide a three-dimensional scaffold to preserve the space of the defect in anticipation of the formation of new tissue. It is necessary for cell adhesion and migration.

The ideal scaffold for tissue engineering should be :

1. Easy to handle.
2. Allow for the incorporation of cells.
3. Allow for the free diffusion of cells and growth factors.
4. Permit the establishment of a vascular bed to insure survival of the implanted cells.
5. Induce a minimal inflammatory response.
6. Be ultimately biodegradable.



STEM CELLS

What are stem cells?

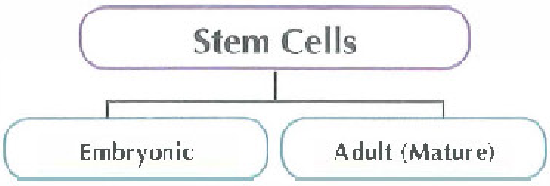
Stem cells are unique cells that have the ability to replicate and differentiate into other cell types and tissues.

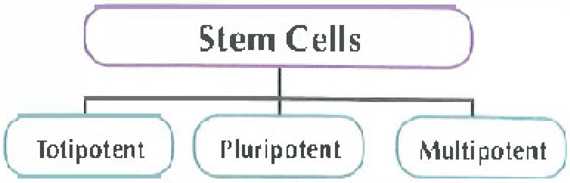
Stem cells are central to three processes in an organism: development, repair of adult tissue and cancer.

Where Stem Cells are Located ?

Any tissue or organ in stasis or undergoing repair and having a connective tissue compartment, has resident populations of mesenchymal stem cells.

CLASSIFICATION





Embryonic stem cells are pluripotent, meaning they can divide and grow rapidly and differentiate into the 220 tissue types that make up the human body

Pluripotent mesenchymal stem cells can be utilized for the replacement of potentially multiple tissues of mesodermal origin (i.e., bone, cartilage, muscle, adipose tissue etc.....

Mature stem cells are multipotent, meaning they can yield all of the cell types associated with the tissues from which they originate

Mature stem cell is an undifferentiated (unspecialized) cell that is found in a differentiated (specialized) tissue, which *can renew itself for a lifetime*.

Can mature stem cells become any type of body cell (pluripotent)?

Traditionally, mature stem cells have been considered limited in their potential to become any type of body cell. In other words, they only produce cell varieties within their own lineage or type and are considered multipotent.

Where can mature stem cells be found?

Sources of mature stem cells have been found in areas of the body including bone marrow, blood stream, cornea of the eye, the dental pulp of the tooth, liver, skin, gastrointestinal tract, and pancreas etc.....

What is the most common type of mature stem cell used today?

The mature stem cells associated with those that form blood in bone marrow are the most common type of stem cells used to treat human diseases today.

Human dental pulp stem cells (HDPSCs)

A population of multipotent mesenchymal cells with high proliferative potential .

Pulp stem cells are intimately associated with the blood vessels of pulp tissue. Radiographic studies provided the first evidence that DPSCs are resident UMC within the pulp core of teeth. Their origin from neural crests explains their multipotency.

The nature of these stem cell populations in the pulp is of importance in understanding their potentialities and development of isolation strategies, and allowing for understanding their use in regeneration and tissue engineering.

Properties of Human Dental Pulp Stem Cells

- The capacity of self- renewal.

  Self renewal character: when a stem cell divides, one daughter cell remains as a stem cell while the other daughter cell or progenitor cell differentiates into a particular cell type Keeping one daughter cell as a stem cell is a characteristic trait of stem cell known as self-renewal.

Multi-lineage differentiation:

Can differentiate into multiple mesenchymal cell lineage including:

- ***Cardio Myocytes*** to repair damaged cardiac tissue following a heart attack.
- ***Neuronal*** to generate nerve and brain tissue.
- ***Glial like cells*** (are non neuronal cells that provide support and nutrition and maintain homeostasis in the nervous system.

Chondrocytes to generate cartilage.

Adipocytes to generate fat.

Myocytes to repair muscle.

Osteocytes to generate bone.

- Used with several scaffolds.
- Can be safety cryopreserved.
- Have long lifespan.
- Seem to possess immunoprivilaeges as they can be grafted into allogenic tissues.
- Exert anti-inflammatory abilities.

The most striking feature of human (DPSCs) is their ability to regenerate a dentin pulp like complex that is composed of mineralized matrix with tubules lined with odontoblasts, and fibrous tissue containing blood vessels in an arrangement similar to the dentin pulp complex found in normal human teeth.

How does a stem cell get to know which type of cell it should differentiate into?

Stem cells are basically blank cells

They "know" what type of cell to become due to:

1. Internal genetic coding.
2. External chemical messages.
3. Coming in physical contact with the differentiated cells.

Where DPSCs are found ?

An abundant source of these UMC in permanent teeth is in the dental pulp of impacted third molars. Recently, investigators have discovered a unique type of mesenchymal stem cell in the dental pulp of deciduous teeth, nicknamed SHED (Stem Cells from Human Exfoliated Deciduous Teeth).

Stem cells extracted from the dental pulp of a third molar could be harvested, then directly implanted into the pulp chamber of severely injured tooth. The goal is to regenerate the pulp inside the damaged tooth, preventing the need for endodontic treatment.

How will I know whether or not the stem cells in the pulp of the tooth are viable?

The blood supply to the pulpal tissues enters through the apical area of the tooth. Therefore, when a tooth is extracted, the pulp should appear *Red* in color, indicating that the pulp received blood flow up until the time of removal, which is indicative of cell viability. When a tooth is extracted, if the pulp is *Gray* in color, it is likely that blood flow to the pulp has been compromised, and thus, the stem cells are likely necrotic and are no longer viable for recovery.

Teeth that become very loose, either through trauma or disease often have a severed blood supply, and are not candidates for stem cell recovery. This is why recovery of stem cells from deciduous teeth is preferred after an extraction versus the tooth that is "hanging on by a thread" with mobility.

Pulpal stem cells should not be harvested from teeth with apical abscesses, tumors or cysts.

Why should individuals "bank" their own dental stem cells?

Using your own stem cells (autologous donation) poses fewer risks for developing an immune reaction "graft rejection" following transplantation than using donated tissues. Autologous donation also avoids the risk of contracting pathogens from the transplanted tissue that may induce disease in the new host.

***A parent may ask:* why should I have my children's dental stem cells banked if we already had their umbilical cord stem cells banked?**

Dental stem cells are banked at the time children are 6-7 years of age, up to adults. The timing of dental stem banking has certain advantages over the timing of banking for umbilical cord stem cells:

The banking of dental stem cells is at least 6 7 years later than the banking of umbilical cord stem cells providing several opportunities for recovery and it is less dependent upon the time.

The cord blood stem cells are primarily used today to treat blood diseases whereas the dental stem cells are to be used to treat hard and soft tissue diseases and injuries.

GENE THERAPY

Following physiologic stimulation or injury to the pulp, stem cells in pulp may be mobilized to proliferate and differentiate into odontoblasts by morphogens released from the surrounding protein matrix.

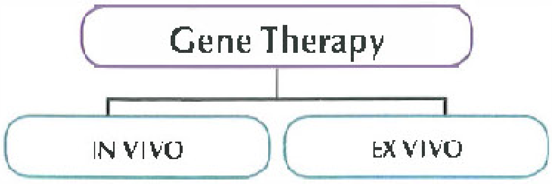
The use of endogenous stem/progenitor cells combined into designed scaffolds with cytokines (BMPs) for local delivery has been demonstrated as a more effective way for tissue engineering.

However, several barriers to effective and safe local delivery of proteins in vivo have been identified :

- Their short life time.
- High costing.
- Difficulty to obtain full bioactivity.
- High dose local delivery associated with both local and systemic toxicity.

To overcome these barriers, gene therapy has emerged as an effective approach by which therapeutic proteins could be carried as genes.

Growth/differentiation factor 11 (GDF11) is a novel member of the BMP family that is found to have the potential to induce reparative dentin formation.



In vivo gene therapy

The healing potential of pulp tissue is enhanced by genes inducing dentin directly applied on the exposed/amputated dental pulp.

The in vivo gene therapy does not have much effect on reparative dentin formation in case of severe inflammation and few stem cells in the pulp tissue.

Ex vivo gene therapy

Pulp stem/progenitor cells are first isolated from pulp tissue and transfected or transduced with some therapeutically proven genes e.g. (Gdf11) to induce differentiation into odontoblasts and dentin-pulp like complex which are then autogenously transplanted on the exposed/ amputated pulp.

In the inflamed pulp under deep caries or trauma, possibly due to the limited supply of pulp stem/ progenitor cells, it might be useful to apply cell-based ex vivo gene therapy compared to in vivo gene therapy.

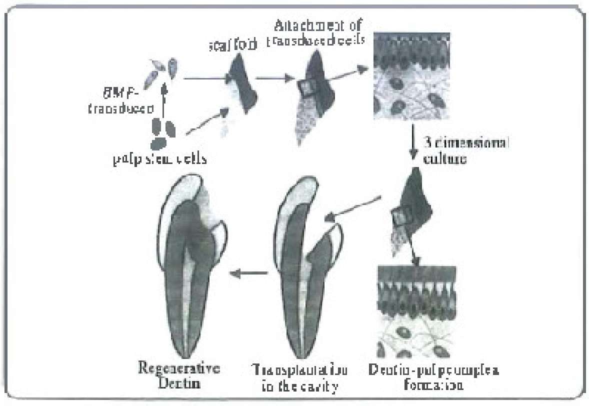


Fig. 1. Ex vivo gene therapy

VECTORS

Are the vehicles of transportation for the genes Vectors are inserted into the target tissue where if properly done, it will release the genes and the genes will become part of the cell.

Methods of injecting vectors

In vivo: Here the vector is injected directly into the tissue (viral vector).

Ex vivo: In this process, the target tissues are first removed, next the cells are modified and cultured in a petri dish. The cultured cells are then put into a vector and the vector is injected into the tissue (non viral vectors).

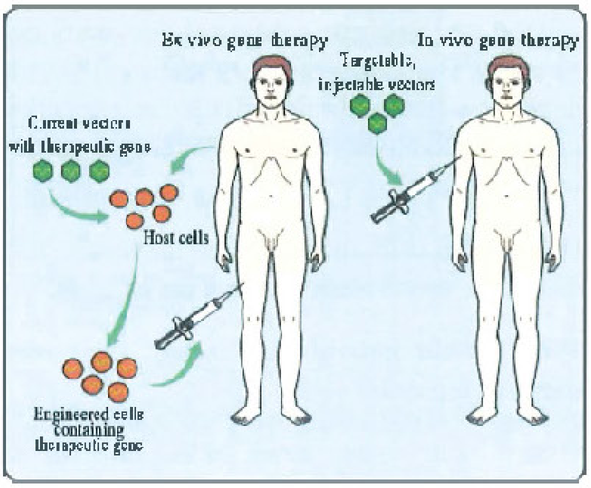


Fig. 2. Methods of injecting vectors

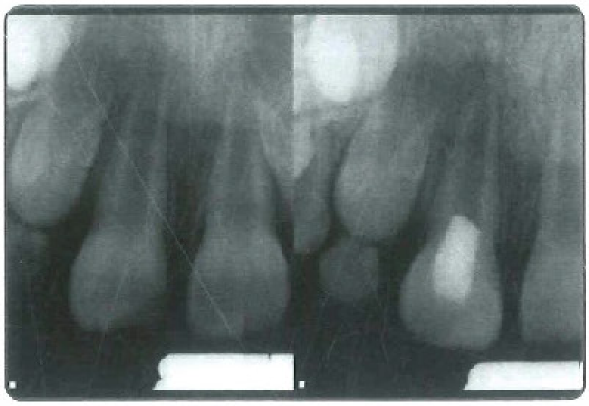
New Concept of Regenerative Endodontics in the Management of Immature Permanent Teeth.

Root Canal Revascularization Via Blood Clotting

Several case reports have documented revascularization of necrotic root canal systems by disinfection followed by establishing bleeding into the canal system via over instrumentation. The revascularization method assumes that the root canal space has been disinfected and the formation of a blood clot yields a matrix (e.g. fibrin) that traps cells capable of initiating new tissue formation

First visit :

Light instrumentation and irrigation with full strength NaOCl, EDTA and CHX then place BiMix (Cipro and Metronidazol). The BiMix is prepared by taking a 500mg Cipro tablet and 500mg metronidazol tablet and crushing them together with a mortar and pestle This powder is mixed with little anesthetic solution.



Second visit (2 weeks later):

Opened tooth, re-irrigated (17% EDTA then NaOCl) to remove the antibiotic paste. Initiated bleeding into the canal using #20 file. Blood should fill the canal up to 2mm below the CEJ so that the formed blood clot will be positioned as high as possible towards the cervical 1/3. The blood column is left to clot (10-20min) while the canal opening is covered with sterile gauze to prevent air borne infection. A thick mix of white MTA is inserted onto the blood clot in small increments using a regular amalgam carrier. MTA is blotted dry of moisture and blood before the next increment was added. This procedure is stopped at about 3mm below the occlusal surface to leave room for the final restoration.

4 and 9 month recall radiographs reveal that the tooth is undergoing apical development, the walls are thickening and a hard tissue barrier has formed under the MTA.

IRRIGATION AND REGENERATION

Future regenerative endodontic procedures may be routinely used to revitalize immature teeth and with continued research eventually even mature teeth.

In order to accomplish regenerative endodontic therapy, it is necessary to stimulate DPSCs attachment to root canal dentin walls.

TWO procedures, carried out during root canal therapy are concerned with this point:

First: Irrigation

Second: Smear layer removal

The numbers of DPSCs attached to root canal surfaces after cleaning and shaping were found to vary according to the use of different irrigating and chelating agents.

Recently the use of a natural irrigant in conjunction with a chelating agent become essential for DPSCs attachment to root canal dentin walls.

NATURAL IRRIGANTS MORINDA CITRIFOLIA

Morinda citrifolia is an exotic plant often called Noni Polynesians have used the fruit juice from the exotic Morinda citrifolia or noni plant for more than 2000 years.

MCJ has a broad range of therapeutic effects, including antibacterial, antiviral, antifungal, antitumor, antihelmintic, analgesic, hypotensive, anti-inflammatory and immune-enhancing effects.

MCJ has been suggested as a natural endodontic irrigating solution.

The irrigation treatment is used in conjunction with a chelating agent to replicate common endodontic practice.

FROM PINK PULP TO PINK GUTTA-PERCHA TO PINK PULP TISSUE AGAIN- THE ERA OF REGENERATIVE ENDODONTICS.

CHAPTER REVIEW QUESTIONS

- Discuss briefly the triad of tissue engineering.
- Define stem cells and mention their classification(s).
- Define gene therapy; mention its types and the different vectors used.
- Discuss briefly the new concept of managing immature necrotic teeth
- Mention the role of irrigation in the regeneration of pulp tissue.

REFERENCES

- Nakasbima M. and Akamine A. : The application of tissue engineering to regeneration of pulp and dentin in endodontics. JOE 31(10):711-718,2005
- Nakashima M.:Tissue engineering in endodontic. Aust.Endod.J.31(3):111-113,2005
- Stem cell research basics Mature stem cells http://www.Kumc.edu/stemcell/mature.html
- Gronthos S., Brahim J., Li W.,Fisher L.W.,Chernan N, Boyds A.Denbesten P. Roby P.and Shi S :Stem cell properties of human dental pulp stem cells J Dent Res 81(8):531-535,2002
- Edwards P.C.andMason J.M. Gene enduced tissue engineering for dental hard tissue regeneration:(2) dentin-pulp and periodontal regeneration.Head &Face Medicine:2-16 ,2006
- Murray P.E, Godoy F.G. And Hargreaves K.M.: Regenerative endodontics A review of current status and a call for action. JOE 33(4):377-389, 2007
- Friedlander L.T.E.,Cullinan M.P., Love R.M.: Dental stem cells and their potential role in apexogenesis and apexification. Int.Endod.J 42(11):955-962,2009
- Murray P.E., Farber R.M., Namerow K.N., Kutter S. And Garcia-Godoy F.: Evaluaion of morinda citrifolia as an endodontic irrigant JOE 34(1):65-70,2008

27

Endodontic Periodontal Relationship

Heba El Far
Laila M. Kenawi

Intended Learning objectives

After reading this chapter, the student should be able to

1. State the pathways of communication between the dental pulp and the periodontium.
2. Describe the effects of pulpal disease and endodontic procedures on the periodontium.
3. Describe the effects of periodontal disease and procedures on the pulp.
4. Identify which clinical diagnostic procedures and findings are of importance in differentiating between primary endodontic and primary periodontal lesions.
5. Establish treatment requirements and sequencing according to diagnostic finding for 1ry endodontic lesions, 1ry periodontal lesion, and combined endodontic-peroiodontal lesions.
6. Mention a new proposed endodontic-periodontal interrelationship classification.

Chapter Outline

Intercommunication between pulpal and periodontal tissues
Physiological pathways
Non physiological pathways:

Influence of pulpal disease and endodontic procedures on the periodontium

Influence of periodontal inflammation on the pulp

Endo-perio lesions (theoretic pathways of osseous lesion formation)
Primary endodontic lesions.
Primary endodontic lesion with secondary periodontal involvement
Primary periodontal lesions
Primary periodontal lesions with secondary endodontic involvement
Concomitant lesions
True combined lesions

Differential diagnosis of endodontic periodontal lesions
Subjective signs and symptoms.
Radiographic findings
Clinical tests.

Treatment alternatives
Endo-perio treatment
Resective approaches
Regenerative approaches

I- Intercommunication between pulpal and periodontal tissues:

1- Physiological pathways:

A- Apical foramen.

B- Lateral (accessory) canals.

C- Dentinal tubules.

D- Palatogingival groove.

A. Apical foramen: (main pathway):

- The ingress of irritants from the necrotic pulp into the periradicular tissues, through the apical foramen, initiates an inflammatory response.
- If plaque covers the root and reaches the apical vessels, this causes pulp inflammation followed by pulp necrosis.

B. Lateral (accessory) canals:

- They may exist anywhere along the root surface but they are found mainly in:
  - The apical thirds of roots.
  - Posterior teeth more than in anterior teeth.
  - Furcation of molars.
- Up to 40% of teeth have lateral or accessory canals.
- They carry toxic substances from pulp to periodontium or vice versa.
- Difficult to identify on the radiograph.
- Positive identification of the presence of lateral canal can be made only when:
  - An isolated lateral lesion is seen radiographically or;
  - During obturation when some of the filling material get extruded into the lateral canal.
- *Etiology:*

  a- Breakdown of epithelial root sheath of Hertwig before root dentin formation.

  b- Persistence of blood vessels between dental papilla and dental sac.

C. Dentinal tubules:

Normally a continuous layer of cementum is an effective barrier to the penetration of bacteria and their by-products. However, when there is a discontinuity in the cementum layer, the dentinal tubules carry toxic metabolites produced during pulpal or periodontal diseases in both directions. This may be due to:

a- Congenital absence of cementum.

b- Removal of cementum during periodontal treatment.

c- Damage to cementum during traumatic injuries.

d- Palatogingival groove:

- Developmental anomalies of the maxillary incisors.
- The groove begins in the central fossa, crosses the cingulum, and extends apically at varying distances.

2- Non physiological pathways:

A. Root perforations:

- An artificial communication between root canal system and periodontium.
- The closer the perforation to the gingival sulcus, the greater chances for apical migration of the gingival epithelium in initiating periodontal lesions.

B. Vertical root fracture:

- Can form a communication between the root canal system and the periodontium.
- The fracture site provides an entry of the bacteria and their toxic products from root canal system to the surrounding periodontium.

II- Influence of pulpal disease and endodontic procedures on the periodontium:

Pulpal disease:

Irritants from necrotic pulp can pass through the apical foramen and lateral canals producing inflammation in the periodontium.

Periodontal tissue destruction starts apically and potentially migrates toward the gingival margin thus termed *retrograde periodontitis* to be differentiated from marginal periodontitis in which the disease proceed from the gingival margin to the root apex. This inflammation is reversible if root canal treatment is properly done.

Endodontic procedures:

Iatrogenic errors, as extension of files, reamers or obturating materials, perforations of pulp chamber floor, perforation of root during cleaning, shaping and post space preparation perforations, vertical root fracture adversely affect the periodontium.

III- Influence of periodontal inflammation on the pulp:

Periodontal disease:

Progressive periodontal diseases result in apical migration of epithelial attachment and root surface exposure to oral cavity and to irritants (bacterial plaque).

Periodontal procedures

- Deep periodontal curretage may sever the apical vessels resulting in pulp necrosis.
- Scaling and planing of root surfaces may remove cementum opening dentinal tubules and lateral canals.
- Also the chemicals and medicaments used during periodontal therapy may cause pulpal damage.

Effects depend on remaining dentin thickness -

If the remaining dentin thickness <2mm→ damage to pulp would be place.

IV- Endo-Perio lesions (theoretic pathways of osseous lesion formation) Fig. 1

1- Primary endodontic lesions.
2- Primary endodontic lesion with secondary periodontal involvement.
3- Primary periodontal lesions.
4- Primary periodontal with secondary endodontic involvement.
5- Concomitant lesions.
6- True combined lesions.

1- Primary endodontic lesions:

- Endodontic lesions resorb bone apically and laterally and destroy attachment apparatus adjacent to a tooth with a necrotic pulp.
- Caries, restoration, traumatic injuries are the most common causes.
- Sometimes an acute exacerbation of a chronic apical lesion in a non vital tooth which may drain coronally through the periodontal ligament into the gingival sulcus, thus mimic clinically the presence of a periodontal abscess.
- But actually these are lesions with narrow sinus tracts (the suppurative process may cause a sinus tract along the periodontal

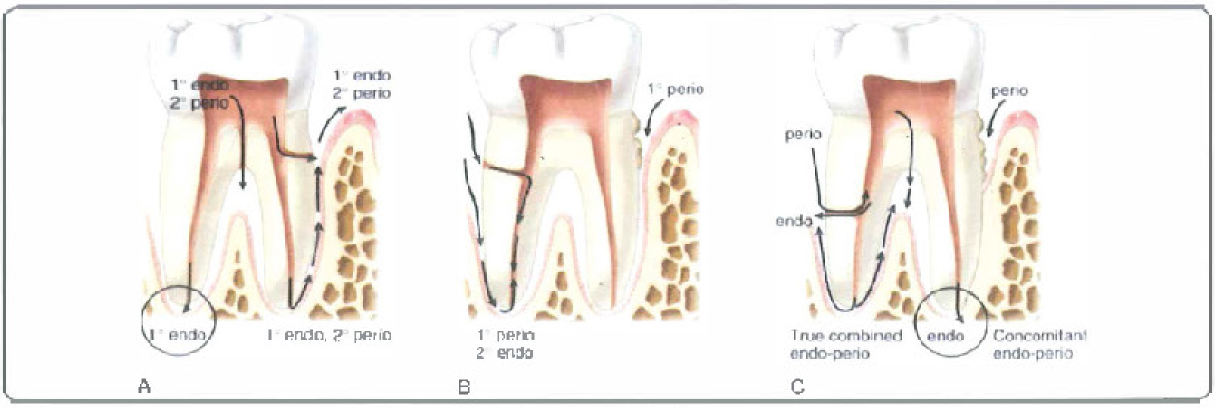


Fig. 1 Endodontic and periodontal pathways

ligament space and open into the gingival sulcus). This sinus tract can be traced down to the tooth apex where no increased probing depth otherwise around the tooth.

- In multirooted teeth the sinus tract can drain off into the furcation area and resemble a 'through and through' furcation defect resulting from a periodontal disease.
- Radiographically: Radiolucent area but normal gingival sulcus.
- Clinically:
  - Pain or asymptomatic with a history of acute exacerbation.
  - Tenderness to pressure and percussion.
  - Increased tooth mobility.
  - Swelling of the marginal gingiva simulating a periodontal abscess.
  - Negative pulp tests.
- Treatment; Root canal treatment without any periodontal treatment.
- Prognosis: Good if proper root canal treatment is done.

2- Primary endodontic lesion with secondary periodontal involvement

- When a lesion of endodontic origin is not treated destruction of periapical alveolar bone will progress to the interradicular area causing breakdown to hard and soft tissues. The accumulation of plaque and calculus will result in periodontal disease and further apical migration of attachment.
- Isolated deep pockets.
- The affected tooth with:
  - Necrotic pulp or failed root canal treatment.
  - Plaque and calculus.
- Treatment: Both root canal treatment or retreatment and periodontal treatment are required.
- Prognosis: If root canal treatment is properly done, the prognosis depends on the severity of periodontal involvement and the efficacy of periodontal treatment.

3- Primary periodontal lesions:

- Periodontal disease begins in the sulcus and migrates to the apex due to accumulation of plaque and calculus resulting in loss of alveolar bone and supporting periodontal soft tissues. This leads to loss of clinical attachment and periodontal abscess.
- Characterestics:
  - Wide spread generalized bony lesion.
  - Tooth mobility.
  - +ve pulp testing.
- Treatment: long term periodontal treatment.
- Prognosis: Depends exclusively on the outcome of the periodontal therapy.

4- Primary periodontal with secondary endodontic involvement:

- These lesions may be indistinguishable from primary endodontic lesions with secondary periodontal involvement.
- Teeth with deep pockets, extensive periodontal disease and possible history of past periodontal therapy.
- When the pulp becomes involved, patient reports accentuated pain and clinical signs and symptoms of pulpal diseases.
- Treatment: both: Root canal treatment and periodontal treatment are required.
- Prognosis: Depends on continuing periodontal treatment subsequent to endodontic treatment.

5-Concomittant pulp and periodontal lesions:

- Both diseases exist but no evidence that either disease has influenced the other (periodontal and endodontic problem with no communication).
- Treatment; Both lesions must be treated concomitantly.
- Prognosis: Slightly better than true combined lesions.

6- True combined lesions

- Pulpal and periodontal diseases may occur independently in and around the same tooth, where merging of apical pulpal lesion and progressive apical extension of periodontal pocket (endodontic and periodontal lesions coalesce) Fig. (2).
- Treatment: Root canal- treatment + periodontal treatment.
- Prognosis: Poor prognosis.

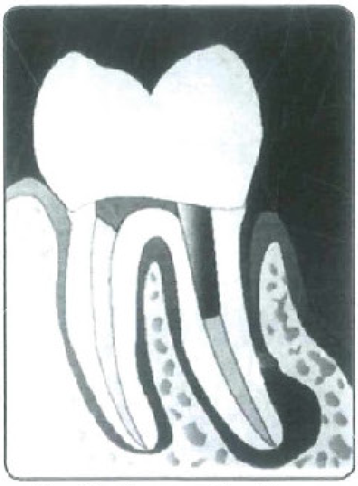


Fig.(2) True combined lesion

A new endodontic-periodontal interrelationship classification , based on the primary disease with its secondary effect, was suggested by Al Fouzan in 2014:

1. Retrograde periodontal disease:
   a. Primary endodontic lesion with drainage through the periodontal ligament,
   b. Primary endodontic lesion with secondary periodontal involvement.
2. Primary periodontal lesion;
3. Primary periodontal lesion with secondary endodontic involvement;
4. *Combined endodontic-periodontal lesion;* tooth has a pulpless, infected root canal system and a coexisting periodontal defect. An attempt is made to identify the primary cause of a combined lesion but this may not always be possible.
5. *Iatrogenic periodontal lesions.* Lesions produced
   a. *Root Perforations*
   b. *Coronal Leakage*
   c. *Dental Injuries or Trauma*
   d. *Chemicals Used in Dentistry*
   e. *Vertical Root Fractures*

V- Differential diagnosis of endodontic periodontal lesions

1- Subjective signs and symptoms.
2- Radiographic findings.
3 Clinical tests.

1- Subjective signs and symptoms:

- When there is little or no pain: Periodontal disease is a chronic and generalized process.
- While acute pain requiring analgesics is associated with pulpal and periradicular lesions.

2- Radiographic findings:

- Periodontal disease is generalized and associated with angular bone loss,causing bone resorption in a cervical to periapical direction.
- Periapical lesions result in damage of the apical periodontium and may extend cervically.

3- Clinical tests:

a. Pulp testing.
b. Periodontal probing.
c. Palpation.
d. Percussion.
e. Visual examination.
f. Tracing of sinus tract.

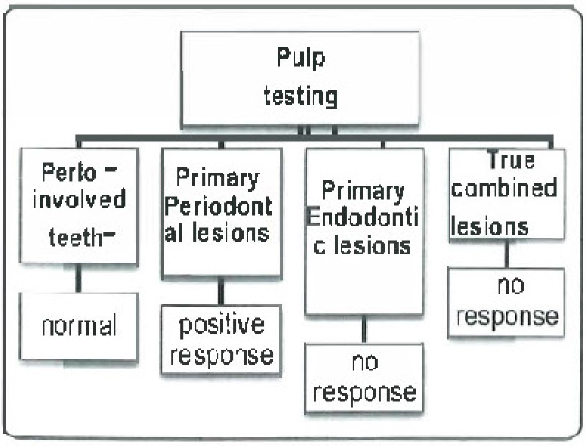


Fig. 3. Diagramatic representation of response to pulp testing

a- **Pulp testing:**

b- Periodontal Probing

- Periodontal lesions: The defects are wide and don't extend apically.
- Endodontic lesions: The defects are narrow and extend to apical foramen or openings of lateral canals.

c- Palpation

- In advanced stages is of no value.
- In early stages may help.

d- Percussion

- Unreliable because both periodontal and endodontic lesions cause inflammation in the periodontal ligament.

e- Visual examination

- Teeth with primary endodontic lesions are associated with caries, extensive or fractured restoration or teeth, history of trauma, attrition.
- Teeth with primary periodontal lesions are associated with plaque or calculus deposition as well as generalized gingivitis or periodontitis.

Table 1. Showing differential diagnosis between pulpal and periodontal diseases:

	Pulpal	Periodontal
	Clinical	
Etiology	Pulp infection	Periodontal infection
Vitality	Nonvital	Vital
Restoration	Deep or extensive	Not related
Plaque/calculus	Not related	Primary cause
Inflammation	Acute	Chronic
Pockets	Single, narrow	Multiple, wide coronally
	Radiograph	
Pattern	Localised	Generalized
Bone loss	Wider apically	Wider coronally
Vertical bone loss	No	Yes
Periapical bone	Radiolucent	Not often related
	Histopathology	
Junctional epithelium	Noapical migration	apical migration
Granulation tissue	Apical (minimal)	Coronal (larger)
Gingiva	Normal	Recession

VII.<u>Treatment alternatives</u>

1- Endo-perio treatment.

- When traditional endodontic and periodontal treatments prove insufficient to stabilize an affected tooth, the clinician must consider treatment alternatives which often consist of resection or regenerative approaches.

2- Resective approaches.:

- Focus on eliminating the diseased roots or teeth.
- Root resection is the removal of a root, with accompanying odontoplasty before or preferably after endodontic treatment.

- Formerly it was used when root canal therapy was considered too difficult, but now its indications are restricted to multirooted teeth in which one or more roots cannot be saved.
- The indications for root resection often include (but are not limited to) root fracture, perforation, root caries, dehiscence, fenestration, external root resorption involving one root, incomplete endodontic treatment of a particular root, severe periodontitis affecting only one root, and severe grade II or grade III furcation involvement.
- Root resection is a technique-sensitive procedure requiring:
  - A careful diagnostic process for selection of teeth that would likely be successful candidates
  - Meticulous interdisciplinary treatment. Factors such as occlusal forces, tooth restorability, and the value of the remaining roots must be examined before treatment.
  - A carefully constructed treatment plan is essential to the success of this resection procedure.

3- Regenerative approaches:

- Regenerative efforts are aimed at restoring lost biologic structures. The concepts of guided tissue regeneration (GTR) or guided bone regeneration (GBR) have been used to promote bone healing after endodontic or periodontal surgery.
- Theoretically, the GTR barrier:
  1. Prevents contact of epithelial and connective tissue with the osseous walls of the defect
  2. Protecting the underlying blood clot.
  3. Stabilizing the wound.
- When GTR is considered, the combined endodontic and periodontal lesion probably has the least favorable prognosis compared with cases having only a periodontal lesion.
- Many varieties of GTR membranes are available for clinical use: resorbable and non- resorbable, but it is logical to use bioresorbable collagen and polymer membranes in endodontic surgeries because there is often no need for a second surgery to retrieve the membrane.

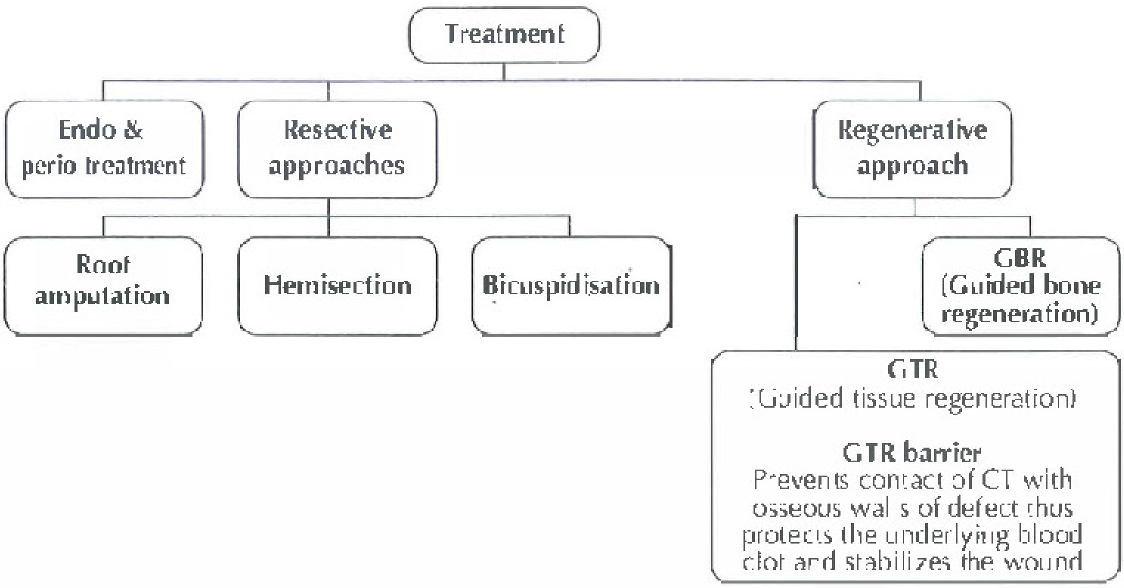


Fig. 4. Different treatment plans for Endo-perio diseases.

CHAPTER REVIEW QUESTIONS

1- What are the pathways of communication between pulpal and periodontal diseases?

2- Explain the effects of pulpal disease and endodontic procedures on the periodontium and the effects of periodontal disease and procedures on the pulp

3- Identify the clinical , radiographic, treatment and prognosis of primary endodontic lesions

4 Mention a new endodontic-periodontal interrelationship classification.

5- Describe briefly the treatment alternatives for teeth with endo-perio lesions?

REFERENCES

- Garg N, Garg A.Textbook of Endodontics.1st ed.JP. ; 314-322, 2007
- DG, Glickman GN. Endodontic and Periodontal Interrelationships. In Hargreaves KM, Cohen S Pathways of the Pulp. 11th ed Elsevier. e45-e61, 2016
- Al-Fouzan KS. New classification of endodontic-periodontal lesions. Int J Dent. 2014;2014:919173. doi: 10.1155/2014/919173. Epub 2014 Apr 14.
- Singh P. Endo-Perio Dilemma: A Brief Review. Dent Res J , 2011:8(1):39-47.
- Jivoinovici R, Suciu I, Dimitriu B, Perlea P, Bartok R, Malita M, Ionescu C. Endo-periodontal lesion--endodontic approach. J Med Life. 2014 Oct-Dec:7(4):542-4.

28 Root Resorption

Reham Seyam

Intended Learning objectives

After reading this chapter, the student should be able to

1. Classify types of root resorption.
2. Describe etiological causes for external and internal root resorption.
3. Describe the diagnosis and differentiation between internal and external root resorption.
4. Describe appropriate treatment strategies for internal and external root resorption.

Postgraduate students should be able to

1. Assess incidence and prevalence of different root resorption types
2. Compare different root resorption classifications
3. Discuss molecular basis for root resorption (cells and mechanism)
4. Discuss theories of resistance against root resorption
5. Assess accuracy of in vivo (markers) and recent radiological (CBCT, microCT, nanoCT) identification for root resorption
6. Discuss hyperplastic root resorption
7. Correlate management of external cervical root resorption to Heithersay classification
8. Compare internal tunneling root resorption versus internal replacement root resorption
9. Evaluate different obturation techniques for internal root resorption cases
10. Evaluate different repair materials for root resorption cases
11. Assess anti-resorptive agents used for root resorption management
12. Discuss pericanalar root resorption resistant sheet (PRRS)
13. Correlate ADA prognosis classification to management of root resorption

Chapter Outline

Definition:

Root resorption is a physiologic or a pathologic process, which results in loss of the cementum and/or dentin of the root of a tooth.

Classification:

Root resorption could be classified according to the site of origin into:

1- **Internal root resorption:** affecting inner surface of the pulp space.

It can be subclassified into:

a- Transient: self limiting that repairs by it self.

b- Progressive (Inflammatory): that progresses due to presence of inflammation, requiring continuous stimulation by infection.

c- Replacement: in which the resorbed dentin is replaced by bone.

2- **External root resorption:** affecting outer surface of the root.

It can be subclassified into:

a- Surface: small superficial cavities in cementum and outermost dentin. It is self limiting and heals by itself.

b- Inflammatory: resorption reaches dentinal tubules that progresses due to presence of inflammation allowing possible communication with the pulp. It is generally related to the presence of bacteria.

c- Replacement (ankylosis): in which the resorbed root surface is replaced by bone. It usually occurs in severe trauma disrupting and injuring the periodontal ligaments.

Another classification of external root resorption is according to its location in the root:

a- Apical b- Cervical c- Lateral

Frank has delineated another type of cervical external root resorption:

He termed it "Extracanal Invasive Resorption" Fig (1) that is divided to:

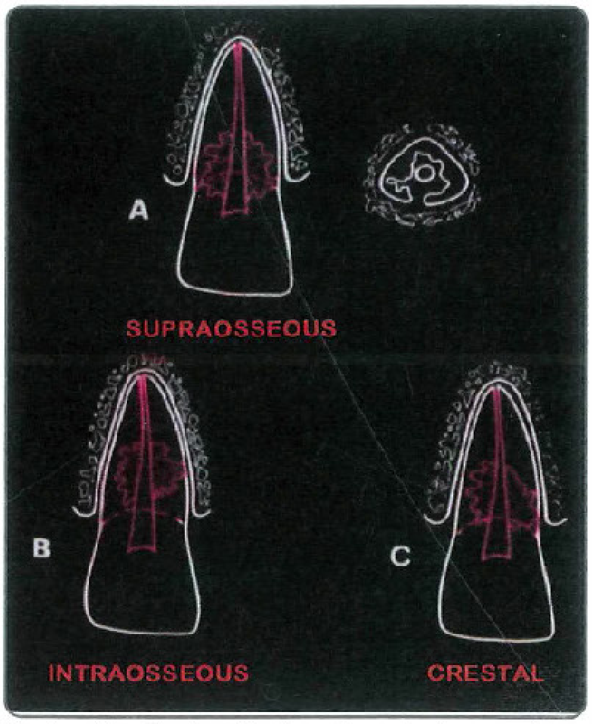


Fig. 1. Frank's classification of cervical external root resorption (external invasive root resorption)

i- Supraosseous lesion; above crestal bone.

ii- Intraosseous lesion; below crestal bone

iii- Crestal lesion is at crestal bone.

Main etiology for root resorption:

Internal root resorption:

Damage of protective odontoblast/ predentin layer, exposing the underlying mineralized dentin to odontoclasts and micro-organisms.

Damage of protective odontoblast/ predentin layer by:

1. Pulpal metaplasia: this might be due to differentiation of giant cells in the pulp due to toxic materials or by the action of diathermy in the presence of sufficient vascular bed for resorptive process.

2. Trauma: accidental blow or traumatic cavity preparation causes intrapulpal hemorrhage. The hemorrhage organizes forming proliferating granulation tissue which compresses the dentin walls.

This causes disappearance of odontoblasts and predentin layer. Odontoclasts differentiate from the connective tissues and resorption begins. Necrosis of the pulp might develop as the destruction becomes extensive and pulp communicates with oral fluid after perforation of the root.

3. Inflammation/infection of the pulp: caries/ periodontal infections, excessive heat during restorative procedures, Ca(OH)2 procedures, vital root resections act as triggering mechanism for internal resorption.
4. Endocrine dysfunction and systemic disease: have been suspected as possible cause for internal resorption
5. Herpes zoster: was linked to resorption in some cases. The Varicella – Zoster virus remains dormant in nerve ganglion from an earlier chickenpox attack and can suddenly be reactive to infect the pulp.
6. Idiopathic changes: Internal resorption occur due to unknown cause.

External root resorption:

Damage of protective cementoblast/PDL/ precementum layer, exposing mineralized cementum to osteoclasts and micro organisms.

Damage of protective cementoblast/PDL/ precementum layer is due to:

1. Inflammation: Root resorption due to periapical inflammation is caused by pulpal involvement, where the pulp is either necrotic or chronically inflammed, causing bacterial toxins and cell degradation products to start an inflammatory reaction which stimulate phagocytic and osteoclastic activity in periapical tissues.
2. Infection: The presence of microbes, decrease pH in periodontium leading to decalcification of bone and tooth. Root resorption was found three times more in periodontally affected teeth than healthy ones.
3. Orthodontic treatment pressure: forces exceeding the limit of the periodontal resistance, denies tissues time to repair. This causes necrosis of periodontium. Macrophages in their attempt to remove the necrotic tissues releases prostaglandin which stimulate resorption. Fixed orthodontic appliances cause more apical root resorption than removable ones.
4. Pathological (tumor or cyst): Tumor or cyst secrete local factors or provide mechanical stimulation (pressure) leading to root resorption as the lesion expands.
5. Impaction: The impacted tooth compresses the surrounding tissues, disrupts blood supply and stimulates resorption.
6. Replantation: Root resorption following replantation of avulsed tooth occur in 80-96% of the cases. It might be surface, inflammatory or replacement resorption. To prevent it, replantation should be within 30 min after avulsion and delay endodontic treatment after replantation and splinting, as delaying replantation risks periodontal cell death
7. Chemical trauma: Acids and bleaching agents might leak from the pulp chamber or canal to the periodontal space via dentinal tubules. This leads to vitality loss in periodontium and inflammatory resorption.
8. Systemic: Root resorption might be caused by hypoparathyroidism, Goucher's disease, Turner syndrome, calcinosis, Herps Zoster and other diseases affecting endocrine system and disturb normal physiologic calcium metabolism.
9. Idiopathic: Root resorption is associated with hemifacial atrophy (Parry-Romberg Syndrome). The active stage of the disease coincides with root formation period of the permanent teeth (from the middle of the first decade into adolescent years)

For **External Cervical Resorption**, damage of protective cementum layer at CEJ might be due to intracoronal bleaching, periodontal therapy, dental trauma, orthodontic treatment and idiopathic etiology.

Diagnosis and differential diagnosis:

1- Clinical signs and symptoms:

Clinically internal and external root resorption are asymptomatic and only detected during routine radiograph or clinical examination. Pink spot that was diagnostic for internal resorption was also found for external cervical resorption that needs further differential diagnosis to identify the condition. Sometimes external cervical resorption could be identified by probe catching, spontaneous profused bleeding on probing, sharp and thinned out edges around the resorptive cavity. Fig. (2)

2- Sensitivity testing:

Internal root resorption usually occurs in teeth with vital pulps and gives a positive response to sensitivity testing. However, the pulp might have become necrotic after perforating resorption has taken place. External inflammatory resorption in the apical and lateral aspects of the root involves an infected pulp space, so gives a negative response to sensitivity tests. While, cervical external root resorption is usually associated with positive response to sensitivity testing unless there is pulpal involvement (in advanced cases).

So to differentiate between internal and external root resorption is very challenging and needs radiographic examination.

3- Radiographic examination:

Radiograph is essential for root resorption detection but smaller lesions are more difficult to identify than larger ones. Internal resorption has well defined margin and the shadow of the pulp space fades out in the resorptive lesion, while external root resorption has ragged margins and the shadow of the pulp space passes unaltered through the resorptive lesion. Fig. (3)

They are better differentiated by mesial or distal **Shift Technique** as the internal resorption defect will not change position in

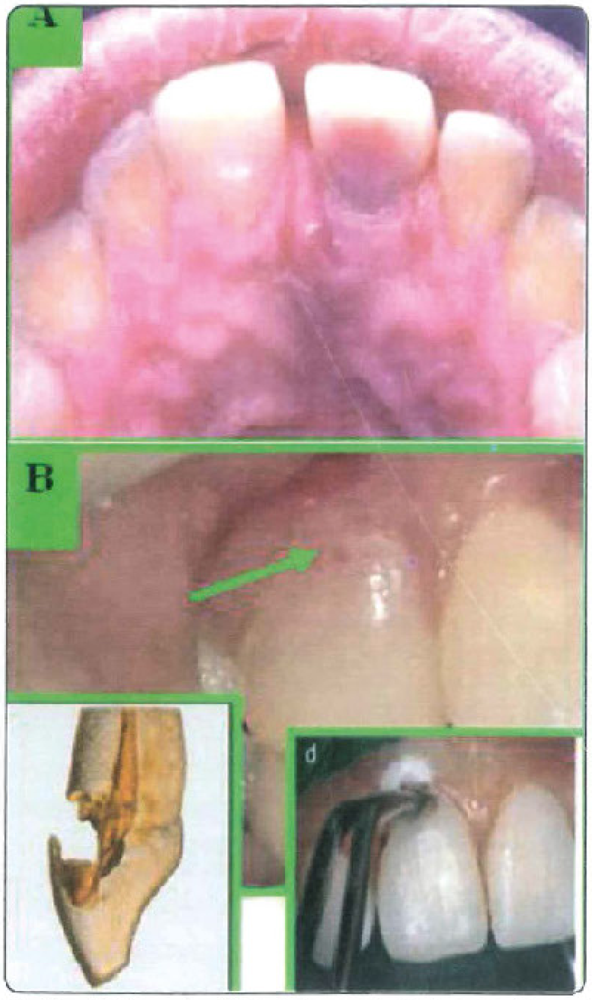


Fig. 2 Pink spot a clinical diagnostic feature for internal resorption (A) that might be missdiagnosed with cervical external resorption (B). Cervical resorption might be diagnosed clinically by probe catching.

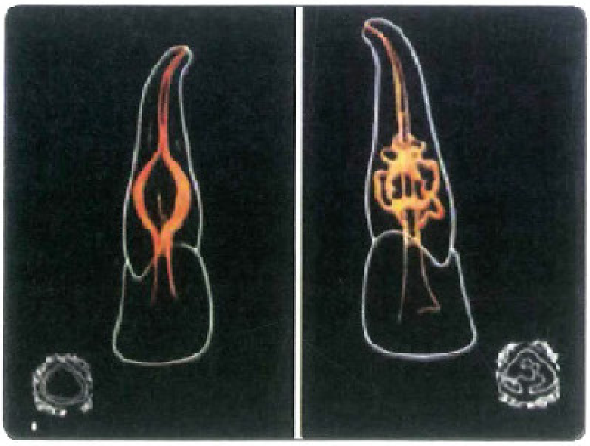


Fig. 3 Schematic drawing representing radiographic appearance of internal resorption (left side) and external resorption (right side).

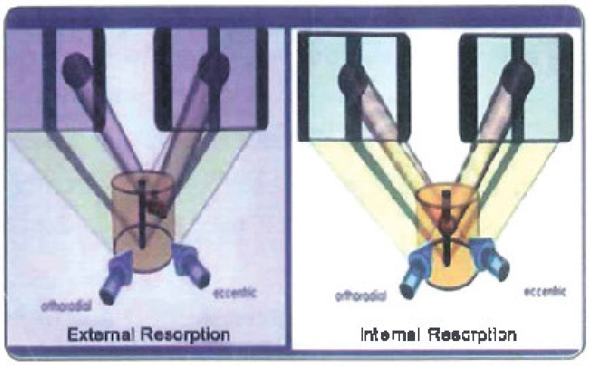


Fig. 4. Mesial or distal X-ray shift technique to differentiate type of root resorption. Internal resorption, the defect does not change position with change in X-ray angulation (right side). External resorption, the defect changes position (left side).

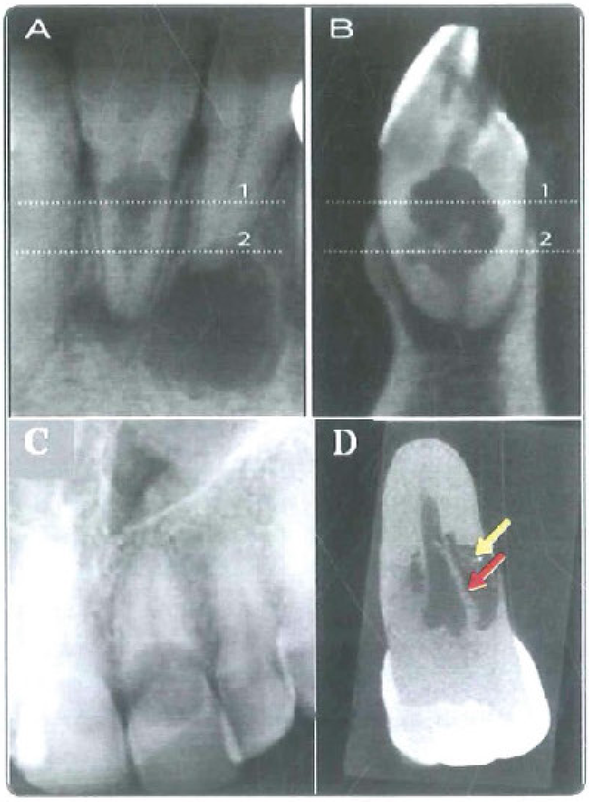


Fig. 5. Radiographic appearance of internal resorption (A) and external resorption (C) that were confirmed byCBCT (B and D) respectively

different angled radiographs as it is within the confines of the root. While external resorption defect will change position as it is on the root outer surface superimposed over the canal Fig. (4).

Internal resorption might be confused with dental caries. However, dental caries is less sharply defined than internal resorption.

Recently **CBCT** (Cone Beam CT) is very diagnostic and more precise in differentiating between internal and external resorption as well as identifying the defect size and if it was perforating defect or not. Fig. (5)

Radiographically, in replacement external resorption, the root is not apparent with no periodontal space delination and replaced by bone trabeculation Fig. (6)

Fig. 6. A case of Replacement resorption (ankylosis). Clinically the tooth not fully erupted and radiographically the root is resorbed and replaced with bone

Treatment of internal resorption:

1- Non-surgical endodontic treatment:

Endodontic treatment is done provided that the defect does not perforate the canal wall and the endodontic triad can be fulfilled.

Problems faced and how to solve:

1- Hemorrhage due to vital pulp which can be controlled by irrigation with 5.25% NaOCl, hemostatic agents and vasoconstrictors. If bleeding cannot be controlled surgical approach should be done because of the possibility of perforation.

2- Remnants of pulp tissues in the inaccessible recesses contribute to treatment failure with a widened void inside the canal cannot be adequately instrumented. This defect needs ultrasonic debridement, irrigation with 5.25% NaOCl to dissolve necrotic pulp tissue and long term $Ca(OH)_2$ medication.

3- Filling technique of choice should seal canal apical to the resorbed area with guttapercha by lateral or vertical condensation. Then the defect is sealed with **Thermoplasticized injected warm gutta-percha** as it gives an impression like reproduction of the irregularities of the root canal space.

2- Recalcification with $Ca(OH)_2$:

Teeth with perforating resorptive defect of moderate size that do not communicate with gingival sulcus or periodontal pocket were successfully treated with long term $Ca(OH)_2$ recalcification. $Ca(OH)_2$ powder mixed with saline, distilled water or anesthetic solution to a thick paste was found to promote hard tissue formation in small to moderate defects.

Theories have been postulated to explain its biological activity and mode of action of $Ca(OH)_2$:

* One theory discussed its high alkaline pH for initiating matrix formation by formative cells stimulation.
* Another theory postulated that a high pH neutralizes the acidic products of the resorptive cells creating an unfavorable environment for them.
* In addition the presence of Ca ions may activate ATPase which may enhance dental tissue mineralization.
* Also, it has an antibacterial effect due to its high pH, destroying microorganisms.

Technique of application:

After control of bleeding and canal debridement with ultrasonics, the canal apical to the defect is obturated $Ca(OH)_2$ is mixed with few drops of saline, distilled water or anesthetic solution to form a thick paste. It is then applied into the pulp chamber and root canal by endodontic pluggers to fill the canal and the defect completely. Post operative radiograph is essential at this step. The patient is recalled in 6 weeks for another film and dressing change. The procedure should be checked at 3 months intervals with radiographic and clinical examination. Repair might be observed from 6 months up to 20 months post-operatively Repair is by deposition of cementum like or osteoid like tissue at site of the defect.

3- MTA application:

Recently in perforated cases MTA (mineral trioxide aggregate) is recommended to seal the perforation through the root canal either by MTA filling totally the canal along with perforative resorptive defect or the canal apical to the resorption defect is obturated with gutta-percha, and then the resorption defect and associated perforation are sealed with MTA. MTA is the most recommended filling to seal such defects for its setting in presence of moisture or blood, bio-compatibility and high alkalinity allowing for hard tissue repair.

4- Surgical treatment:

When non surgical approach and recalcification requirements can not be met or have been unsuccessful, a surgical approach is required to correct the defect. This approach is to expose and seal the resorptive defect surgically. MTA is the most recommended filling to seal such defects.

Indications for surgical treatment:

* Altered anatomy of root apex by the resorptive process.
* Uncontrollable bleeding from the perforation defect.
* Perforation near or at the epithelial attachment where recalcification cannot be used.
* Unsuccessful recalcification.

5- When internal resorption defect occurred in an inoperable site or has rendered the tooth untreatable or unrestorable, the available treatment options are root resection, intentional replantation or extraction.

Treatment of external resorption

It is imperative in all diagnosed cases of external resorption to remove resorptive tissue and the cause if still present.

External cervical resorption

It is usually due to trauma, bleaching, replanted and ankylosed teeth, or consequence of orthodontic treatment. As it may be a consequence of bleaching the following steps are essential to minimize its probability:

1- Protect the dentinal tubules by placing a layer of cement over the guttapercha at the cervical line to prevent ingress of bleaching materials through dentinal tubules.

2- Eliminate the use of heat of thermocatalytic procedure.

3- Avoid etching of dentin as it opens dentinal tubules and lead to direct path to the gingival tissues.

4- Beware of the caustic nature of Superoxol.

The treatment of such case depends on position of the defect in relation to epithelial attachment:

1. If accessible defect (above or at the epithelial attachment), resorptive tissue should be curetted from the defect.
2. The 90% trichloracetic acid should be topically applied to resorptive defect after protecting adjacent soft tissues with glycerol.
3. Glass ionomer cement should be used to restore the defect.
4. Elective endodontic treatment in the root canal to gain access to deeper and encircling infiltrative channels or when resorptive defect involve or approximate pulp. Ledermix paste intra-canal dressing is recommended, followed by obturation.
5. If inaccessible resorptive defect (below epithelial attachment), expose the resorptive defect by orthodontic extrusion or surgically with full-thickness periosteal flap/ periodontal flap reflection, to allow complete access for curetting of the resorptive lesion and defect restoration. Elective endodontic treatment might be done as above.
6. Leave untreated and monitor.
7. Lesions that are not amenable to treatment, should be extracted and replaced with an implant.
8. **Infection induced communicating (perforating) external- internal resorption:**

   Endodontic treatment to the affected tooth is needed. Induce re-calcification by use of calcium hydroxide alone or following careful topical application of 90% trichloracetic acid. ProRoot MTA may also be used to restore the defect conventionally or surgically.

The surgical restoration of resorptive defect of external cervical resorption can result in a

clinically compromised conditions. Restoration of the resorptive defect results in the development of a periodontal pocket because the tissue cannot attach to the filling material. A recent study reported a high success rate with the application of GTR techniques (Guided tissue regeneration) for the treatment of cervical resorption. The idea beyond this technique is that it permits the growth of new attachment into the defect.

The American Academy of Periodontology has defined GTR procedures as those used to regenerate lost periodontal structures through differential tissue response:

The best results occurred when periodontal ligament cells populate the root surface first as ideal new connective tissue attachment develops.

If cells from the gingival epithelium meet the root surface, root resorption occurs.

If bone cells come in contact with the root surface, root resorption and ankylosis occur.

Lateral root resorption

Luxative injury is a major cause for external root resorption on the lateral aspect of the root. Intrusion trauma produces higher incidence of external resorption than other luxative injuries. Two types of lateral resorption exist: non perforating and perforating. In non perforating, and its cause from inside the pulp (pulp necrosis), non surgical endodontic treatment with $Ca(OH)2$ dressing is needed and follow up.

In perforating lesions, the external resorption reaches dentin and perforates the root canal, recalcification with $Ca(OH)2$ should be attempted after canal debridement to stop destruction process and stimulate repair by deposition of new tooth structure. This is followed up every 3 months up to 2 years, clinically by direct examination through the access and radiographically for evidence of hard tissue repair. When a physical barrier has been established, the defect is filled with guttapercha.

If it was non perforating and caused by other causes not from the pulp, or recurrence occur after endodontic treatment or recalcification, surgical treatment is needed with MTA to restore the defect. Other materials used to seal the defect as amalgam, IRM, Cavit, composite resin or glass ionomer.

If it was irrestorable or inaccessible for treatment, extraction is needed.

Apical root resorption

Periapical inflammation may result in apical root resorption. Non surgical endodontic treatment with apical stop formation during cleaning and shaping is needed against which guttapercha is condensed. The removal of necrotic pulp should be followed by intra-canal medication with Ledermix paste. If resorption is severe inverted cone or tailor made technique are indicated. If resorption has enlarged the apical portion of the canal precluding proper instrumentation and sealing, apical closure techniques (recalcification with long-term $Ca(OH)2$ or apical barrier with MTA) should be used. Root canal obturation when resorption is controlled. Usually non surgical treatment is the initial approach for external resorption. When recall radiographs at 6 months or 1year show continued resorption or persistent periapical pathosis, apical surgery should be performed.

Prevention, following replantation of mature tooth could be done by pulp extirpation and Ledermix paste dressing as soon as possible.

Intracanal medications used in inflammatory root resorption:

Ledermix, an antibiotic/corticosteroid paste has been shown to be effective in treating inflammatory resorption by inhibiting the spread of dentinoclasts. Its release and diffusion has been enhanced when used in combination with $Ca(OH)2$.

Calcitonin, a hormone known to inhibit osteoclastic bone resorption was studied to evaluate its effect on root resorption. Histological results showed that calcitonin was an effective medication for the treatment of inflammatory root resorption and could be a useful therapeutic adjunct in difficult cases of external root resorption. Calcitonin is applied as a root canal dressing that passes via the dentinal tubules directly to the external cervical resorptive lesion.

Some other potential medicaments used with this method are **osteoprotegerin and bisphosphonates.**

External replacement resorption treatment: (ankylosis)

Mature tooth in normal occlusion:

Leave and monitor for ultimate implant replacement.

Mature/immature tooth in infra-occlusion:

1- Surgical reposition with root surface treatment with Emdogain.
2- Decoronation and submerge to maintain alveolar growth.
3- Vertical distraction.
4- Prosthetic elongation.
5- Implant therapy, if necessary, when alveolar growth completed.

Chapter Review Questions

1. Define and classify types of root resorption.
2. Describe causes of external root resorption.
3. Describe causes of internal root resorption.
4. Differentiate diagnostically between internal and external root resorption.
5. Describe appropriate treatment strategies for internal root resorption.
6. Describe appropriate treatment strategies for external root resorption.

References

- Haapasalo M, Endal U. Internal inflammatory root resorption: the unknown resorption of the tooth. Endodontic Topics 14, 60–79, 2006.
- Heithersay GS. Management of tooth resorption. Australian Dental Journal Supplement; 52:(1 Suppl):S105-S121, 2007.
- Patel S, Kanagasingam S, Pitt Ford T. External Cervical Resorption: A Review. J Endod ;35:616–625, 2009.
- Patel S, Ricucci D, Tay F. Internal root resorption: a review. J Endod;36:1107–1121, 2010.
- Trope M. Root resorption due to dental trauma. Endodontic Topics 1, 79–100, 2002.
- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 10th ed. Mosby El Sevier, 2011.

29

Restoration of the Endodontically Treated Teeth

Laila M. Kenawi

Intended Learning objectives

After reading this chapter, the student should be able to

1. Describe the special features of endodontically treated teeth.
2. Recognize features evaluated before restoring an endodontically treated tooth.
3. Describe restorative options.

Postgraduate student should be able to:

1. Describe the special features of endodontically treated teeth.
2. Evaluate endodontically treated teeth prior to treatment planning
3. Select the appropriate restorative techniques and materials for endodontically treated teeth restorative options.
4. Analyze the special features of endodontically treated teeth.
5. Evaluate endodontically treated teeth prior to treatment planning
6. Select the appropriate restorative techniques and materials for endodontically treated teeth restorative options.

Chapter Outline

Introduction

Special features of endodontically treated teeth

Pretreatment evaluation.

Restorative materials and options.

Direct composite restorations

Indirect restorations

Full crown

Post

Core

Treatment options.

The structure and composition of teeth are perfectly adapted to the functional demands of the mouth, and are superior in comparison to any artificial material.

Objectives of endodontic treatment:

The objectives of endodontic treatment are to render the affected tooth:

- Biologically acceptable.
- Symptom free .
- Functioning without a diagnosable pathosis.

- Endodontic therapy is *not* considered complete, unless the *coronal part* of the tooth returns to occlusion and performs complete functions of normal teeth.
- Thus maintaining a coronal seal and placing of a definitive restoration should be considered an essential component of successful endodontic treatment.

I- SPECIAL FEATURES OF ENDODONTICALLY TREATED TEETH:

Forming a unique problem of its own, an endodontically treated tooth usually requires different restorative treatment from vital tooth as it is structurally different and is characterized by:

1. **Loss of tooth structure.**
2. **Altered physical characteristics.**
3. **Altered esthetic characteristics.**

1. Loss of tooth structure.

Resulting from the combined effect of:

a- The prior disease and dental procedures:

Caries, fracture or dental procedures including tooth preparation and restoration (the literature reported 20% to 63% and 14% to 44% reduction in tooth stiffness following occlusal and MOD cavity preparations, respectively) .

b- The endodontic procedures (access preparation, root canal preparation):

Tooth is weakened at the cementoenamel junction from removal of dentin during endodontic treatment:

i. *Endodontic access* into the pulp chamber (deroofing) destroys the structural integrity provided by the coronal dentin of the pulpal roof resulting in greater flexing of the tooth under function.

ii. *Root canal instrumentation* removes dentin.

The decreased volume of tooth structure from the combined effect of the prior disease and dental procedures and endodontic manipulation create a significant potential for fracture of the endodontically treated tooth.

2. Altered physical characteristics.

- Remaining tooth structure after root canal treatment shows altered physical characteristics. Changes in collagen cross linking and dehydration of dentin result in a 14% reduction in strength and toughness.
- Root canal irrigants (NaOCL) and chelators like (EDTA: ethylene diaminetetraacetic acid) interact with root dentin. Sodium hypochlorite (NaOCl) is proteolytic so it interacts with the dentin organic contents while chelators interact with the mineral content of dentin thus reducing elasticty, flexural strength and micro-hardness of dentin.

3. Altered esthetic characteristics.

Darkening of endodontically treated teeth Fig. (1) is a common clinical finding:

Fig. 1. Darkening of endodontically treated tooth

a- Biochemical changes in dentin, modify light refraction through the tooth, modifying its appearance.

b- The endodontic technique may contribute to discoloration through:

- o Incomplete debridment.
- o Intra canal medicaments .
- o Inadequate removal of root canal filling materials.

c- Effect of drilling and pulp removal and changes in tooth composition and thickness.

Summary:

The common clinical findings of root canal treated teeth are:

- o Decreased translucency.
- o Increased fracture susceptibility.
- - Immediate restoration of the endodontically treated teeth is required and the only reason to delay the permanent restoration is a questionable prognosis where failure would lead to extraction.

II- PRETREATMENT EVALUATION

Before any therapy is initiated, the tooth must be thoroughly evaluated to ensure treatment success, this includes.

1- **Endodontic Evaluation.**

2- **Periodontal Evaluation.**

3- **Biomechanical Evaluation.**

4- **Esthetic Evaluation.**

1- Endodontic Evaluation:

- The prerestorative examination should include an inspection of the quality of existing endodontic treatment.
- New restorations especially complex ones should not be placed on abutment teeth with questionable endodontic prognosis.
- Evaluated endodontically treated tooth should exhibit:
  - No sensitivity to percussion or biting pressure.
  - No sensitivity to palpation.
  - No sinus tract.
  - No periodontal probing deeper than 3 mm.
  - No evidence of active inflammatory disease.
  - No radiographic signs of apical periodontitis.
  - No radiographic evidence of:
    * Root canal obturation deficiencies (under or over).
    * Poorly instrumented or condensed canal; improper cleaning and shaping.
    * Untreated (missed) canals.

Otherwise retreatment is indicated

- If a post is to be used so canals obturated with silver points or other inappropriate filling material (as paste) should be retreated .

2- Periodontal Evaluation:

- Maintenance of periodontal health is also critical to the long term success of endodontically treated teeth.
- The periodontal condition of the tooth must be determined before the start of endodontic treatment and restorative phase.
- The following conditions are critical for treatment success:
  - Healthy gingival tissues.
  - Normal bone architecture and attachment level .
  - Maintenance of the biological width and ferrule effect.
- Periodontal disease should be treated before the placement of coronal restoration.

3- Biomechanical Evaluation:

- The initial decay or trauma and the root canal therapy, influence the biomechanical status of the tooth and the selection of the restorative materials and procedures.
- Important factors include:
- The amount and quality of the remaining tooth structure which are more important to the long term prognosis than any restorative material properties.
- The anatomic position of the tooth

a- Anterior; esthetic or posterior; functional

b- The strategic importance of the tooth should be evaluated (maxillary canine, molar).

- The occlusal forces on the tooth; which are affected by:

a- Type of occlusion: normal occlusion, open bite, cross bite, deep intercuspation.

b- Type of opposing occlusion: natural teeth, partial or fixed prosthesis.

c- Anticipated future loading on this tooth and whether it is going to be an individual unit. A part of a complex removable or fixed prosthesis and the amount of shear and horizontal forces on the cervical area as in cases of (abutments and removable prothetic clasps).

- The restorative requirements of the tooth

4- Esthetic Evaluation:

- Thin gingiva may transmit a shadow of the dark root color through the tissue.
- Metal, carbon or amalgam dowels can result in unacceptable gingival discoloration.
- The translucency of all-ceramic crowns must be considered in the selection of dowel and build-up materials.

III. RESTORATIVE MATERIALS AND OPTIONS

- Restoration of endodontically treated teeth should be designed to:
- Replace the missing tooth structure.
- Protect the remaining part from fracture.
- Prevent reinfection of root canal system.
- Several important considerations affect the plan of treatment to restore endodontically treated tooth such as:
- The amount of remaining tooth structure (which affect the long term prognosis of the tooth more than any properties of post, core or crown materials).
- The anatomic position of the tooth.
- The functional load on the tooth.
- The esthetic requirements.

- Although the use of a crown built on post and core is a traditional approach, others have advocated the use of direct composite resins for restoring small defects in endodontically treated teeth.

- More recently, indirect restorations such as overlays or endocrowns made of composite resins or ceramics have also been used.

a. Direct Composite Restorations

- When properly cured, resin composites are highly aesthetic, exhibit high mechanical properties, and can reinforce the remaining tooth structure through bonding mechanisms.

- The shrinkage that accompanies polymerization of contemporary composite resins remains a significant problem to the long-term success of these restorations.

➢ The amount of shrinkage will depend on:

a) The shape of the cavity preparation

b) The ratio of bonded to unbonded (or free) surfaces. This so-called C-factor, a clinically relevant predictor of the risk of debonding and leakage; restorations with high C-factors (> 3.0) are at greatest risk for debonding.

- ➢ A direct composite restoration may be indicated when only one proximal surface of the tooth has been lost
- ➢ Using an incremental filling technique is mandatory to reduce shrinkage stresses during polymerization.

- Classically, direct composite restorations have been placed in anterior teeth that have not lost tooth structure beyond the endodontic access preparation.
- Although direct composite resins may also be used for small restorations in posterior teeth, they are contraindicated when more than a third of coronal tissue has been lost.

b. Indirect Restorations: Composite or Ceramic Onlays and Overlays

- Ceramic or resin composite onlays and endocrowns can also be used to restore endodontically treated teeth. They allow for conservation of remaining tooth structure rather than a full crown.

- **Overlays** incorporate a cusp or cusps by covering the missing tissue.
- **Endocrowns** The endocrown is a restorative option for endodontically treated teeth Fig. (2). It comprises a circumferential butt margin and a central retention cavity inside the pulp chamber and constructs both the crown and core as a single unit. This approach utilizes the surface available in the pulp chamber to ensure the stability and retention of the restoration.

- **Material used:**

i. **Ceramics** are a material of choice for long-term aesthetic indirect restorations because their translucency and light transmission mimic enamel. New materials either are variations of feldspathic porcelains (e.g., In- Ceram, Cerec, IPS Empress) or may be fabricated from other ceramic systems, including alumina, zirconia, or silica. Among these newer compositions is lithium disilicate, which offers high strength, high fracture toughness, and a high degree of translucency. Physical properties of these materials have improved to the point where they can survive high stress-bearing situations such as posterior restorations in endodontically treated teeth.

ii. Onlays, overlays, and endocrowns can also be fabricated from **resin composites processed in the laboratory.**

Fig. 2. Endocrown

◊ Studies showed that cusp coverage for posterior teeth was the only variable that ensured long term success and that the incidence of fracture was six times more for posterior endodontically treated teeth without cusp coverage.

c. Full Crowns

When a significant amount of coronal tooth structure has been lost by caries, restorative procedures, and endodontics, a full crown may be the restoration of choice.

The crown can be directly built on the remaining coronal structure or the cementation of a post inside the root canal might be necessary to retain the core material and the crown

Because most endodontic sealers do not completely seal the root canal space, the coronal seal provided by the placement of a post and core will positively influence the outcome of the endodontic treatment. Finally, the luting material used to cement the post, the core, and the crown to the tooth will also influence the longevity of the restoration. The post, the core, and their luting or bonding agents together form a *foundation restoration* to support the future crown.

The Foundation Restoration: General Considerations

As a general rule, the more tooth structure that remains, the better the long-term prognosis of the restoration.

The coronal tooth structure located above the gingival level will help to create a ferrule Fig (3). ***The ferrule*** is formed by the walls and margins of the crown, encasing at least 2 to 3 mm of sound tooth structure. A properly executed ferrule significantly reduces the incidence of fracture in endodontically treated teeth by reinforcing the tooth at its external surface and dissipating forces that concentrate at the narrowest circumference of the tooth. A longer ferrule increases fracture resistance significantly. The ferrule also resists lateral forces from posts and leverage from the crown in function and increases the retention and resistance of the restoration.

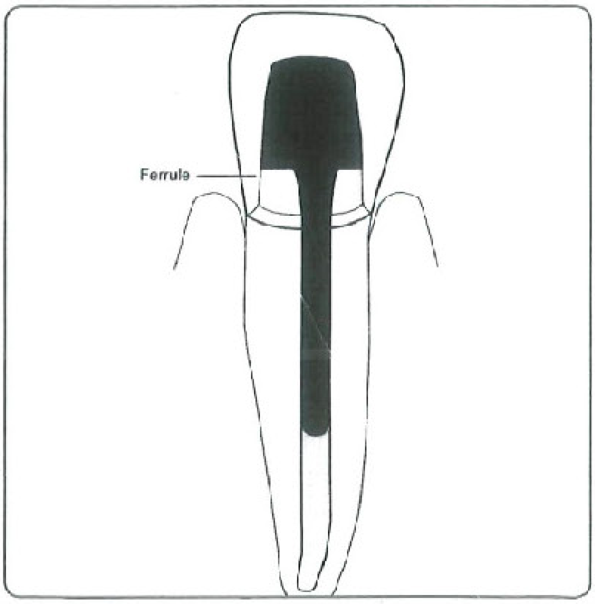


Fig. 3. Ferrule

To be successful, the crown and crown preparation together must meet five requirements:

1. The ferrule (dentin axial wall height) must be at least 2 to 3 mm.
2. The axial walls must be parallel.
3. The restoration must completely encircle the tooth.
4. The margin must be on solid tooth structure.
5. The crown and crown preparation must not invade the attachment apparatus.

Post

1- Definition:

It is a rigid material placed in the radicular portion of a structurally damaged tooth in which additional retention is needed for the core and coronal restoration.

2- Ideal requirements of a post:

a. Provide maximum retention of the core and crown.
b. Easy to place.
c. Less technique sensitive.
d. Have high strength and fatigue resistance.
e. Be visible radiographically.

f. Biocompatible.

g. Easily retrievable when required.

h. Esthetic when indicated.

i. Available and inexpensive.

3- Classification of posts:

a. Prefabricated .

b. Custom made.

a. Prefabricated posts:

- Classified according to material or shape.
- According to material they are classified into:

i. Metal :

- Gold alloy
- High platinum alloys
- Co-Cr-Mo alloys
- Stainless steel
- Titanium and titanium alloys

ii. Carbon fiber posts.

iii. Quartz fiber posts.

iv. Zirconia postss.

v. Glass fiber posts.

vi. Ceramic posts.

vii. Plastic posts

- The main advantage is the simplicity of the technique.
- Usually designed to match with special drills for canal preparation before post insertion.
- Prefabricated posts can also be classified according to shape into:

i. Parallel-sided.

ii. Tapered.

Both can be smooth or serrated or threaded.

- The root canal filling material is removed and the canal is enlarged in size using the rotary instrument that corresponds to the dimension of the selected post.

Fiber Posts

A fiber post consists of reinforcing fibers embedded in a resin-polymerized matrix.

Common fibers in today's fiber posts are made of carbon, glass, silica, or quartz.

The original fiber posts consisted of carbon fibers embedded in epoxy resin, but quartz-fiber posts are currently preferred for their:

i. Favorable mechanical properties,

ii. Aesthetic qualities,

iii. Ability to chemically bond to the polymer matrix.

Current fiber posts are radiopaque and may also conduct the light for polymerization of resin-based luting cements. A light-transmitting post results in better polymerization of resin composites in the apical area of simulated root canals, as measured by hardness values.

It is generally accepted that bonding fiber posts to root canal dentin can improve the distribution of forces applied along the root, thereby decreasing the risk of root fracture and contributing to the reinforcement of the remaining tooth structure.

A well-adapted adhesively cemented fiber post is considered the most retentive with the least stress generated on the canal walls.

Zirconia posts

Zirconia posts exhibit a high flexural strength.

Zirconia posts are aesthetic, partially adhesive, rigid, but also brittle.

Zirconia posts cannot be etched, and available literature suggests that bonding resins to these materials is less predictable and requires substantially different bonding methods than conventional ceramics. When a composite core is built on a zirconia post, core retention may also be a problem.

Overall, there are concerns about the rigidity of zirconia posts, which tends to make those posts too brittle. Other reports indicate that the rigidity of zirconia posts negatively affects the quality of the interface between the resin core material and

dentin when subjected to fatigue testing.

b. Custom made posts:

i. Custom cast metal post and core.

ii. Ceramic custom made posts and cores.

Factors to be considered in post and core design:

I- Retention and resistance form.

II- Preservation of the tooth structure.

1- **Post retention:** *refers to the ability of the post to resist vertical dislodging forces, it is affected by:*

a) Post length.

b) Post diameter.

c) Post design and taper.

d) Luting agent.

e) Root curvature.

a) Post length should be Fig. (4).

Fig. 4. Post length

- 2/3 of the length of the remaining root.
- Equal to or greater than the crown length of the restored tooth.
- AT LEAST 5 MM OF GUTTA PERCHA SHOULD BE RETAINED APICALLY TO ENSURE A GOOD SEAL

b) Post diameter

- Post diameter should not exceed 1/3 the root diameter otherwise the tooth will become weaker.
- It is advisable to maintain a minimum of 1 mm of sound dentin around the post.

c) Post design and taper

- Parallel sided posts are more retentive than tapered ones.
- Threaded posts are more retentive than serrated which are better than smooth.

d) Luting agent

- Cement selection in case of structurally compromised teeth is of special importance because functional forces cause strain against crown margins with possible failure of the cement bond.
- Crown cemented with resin cement are more resistant to force-related failure than resin modified glass ionomer or zinc phosphate cements.

e) Root Curvature:

- When present, post length must be limited as the post should stop before the beginning of the curvature to preserve remaining dentin, helping to prevent root fracture or perforation.

2- **Post resistance:** *refers to the ability of the post and the tooth to withstand the lateral and rotational forces and it is affected by:*

a) Post length

b) Antirotational groove

c) Rigidity

d) Ferrule preparation

Timing of post space preparation:

- It is agreed that removal of gutta-percha at the same visit of obturation may disturb the apical cement seal. So a second visit may be appropriate after setting of the root canal filling for post preparation and placement.

Creation of post space:

- Both rotary and hot hand instruments can be used safely to remove guttapercha when 5 mm is retained apically.

Root selection of multirooted teeth:

Premolars:

When posts and cores are needed in premolars, posts are best placed in the palatal root of the maxillary premolar.

Molars:

Most appropriate roots for posts are roots with greatest dentin thickness and the smallest developmental root depressions. The primary roots in maxillary molars are palatal roots and the distal roots in the mandibular molars. The facial roots of maxillary molars and the mesial root of mandibular molars should be avoided if at all possible.

Luting Cements

A variety of cements have been used to cement endodontic posts and this includes traditional cements, glass ionomer cements, and resin-based luting cements.

Self-Adhesive Cements

More recently, self-adhesive resin cements have been introduced as an alternative to conventional resin-based luting cements.

Core

- **Definition:** The core is a restorative material that replaces the missing coronal structure and retains the final crown.
- The attachment between the tooth, the core and the dowel can be mechanical, chemical or both.
- Pins, grooves can be placed in dentin in order to improve core retention and resistance to rotation at the expenses of the tooth structure, so if used dentin removal must be kept to a minimum.

Desirable physical characteristics of a core:

- High compressive strength.
- Dimensional stability.
- Ease of manipulation.
- Short setting time for cement.
- An ability to bond to both the tooth and the restoration.
- Biocompatability.

Types of cores:

1. *Cast core (metal or ceramic).*
2. *Amalgam cores.*
3. *Composite resin core.*
4. *Glass ionomer core.*
5. *Resin modified glass ionomer cores.*

1- Cast core:

Advantages:

1- The core is an integral extension of the dowel.

2- This construction avoids dislodgement of the core and crown from the dowel.

Noble metal, base metal alloy and ceramic cores can be used.

2- Amalgam cores:

Advantages:

1- High compressive strength and high modulus of elasticity

2- Stable to thermal and functional stress, transmits minimal stress to residual tooth structure, cement and crown margins.

3- Easily manipulated.

4- Amalgam cores are retentive when used as coronal and radicular restorations or with preformed dowel in posterior teeth.

Disadvantage:

Corrosion potential with subsequent discoloration of the gingiva or remaining dentin.

N.B.: AMALGAM USE IS DECLINING WORLDWIDE.

3- **Composite resin core:**
- It exhibits favorable ease of manipulation and very rapid set.
- Recent adhesive dental technologies, improved physical characteristics of composite resin.

4- **Glass ionomer core:**
- Glass ionomer and glass ionomer silver core materials are adhesive (chemical bond) and possess an anti-cariogenic quality.
- Microleakage is less than composite resin or glass ionomer resin.
- Disadvantages: Soluble, sensitive to moisture, low strength and brittle because of low fracture toughness.
- Contraindications: Thin anterior teeth or to replace unsupported cusps.

5- **Resin modified glass ionomer cores:**

Advantages:

1- Exhibit properties of both glass ionomer and composite.
2- Moderate strength.
3- Adequate for moderate size build ups.
4- Minimal microleakage.
5- Solubility value between glass ionomer and composite resin.
6- Fluoride release is equal to glass ionomer and higher than composite.

Disadvantage:

They exhibit hygroscopic expansion which may cause fracture of ceramic crown.

The final configuration of the fully restored tooth has 5 parts Fig. (5).

- The residual coronal and radicular tooth structure, supported by the periodontium.
- The post (dowel), located in the root, which retain the core.
- The core, located in the pulp chamber, which retain the crown.
- The coronal restoration, which protects the tooth and restores function and esthetics.
- The adhesive bonding agents or traditional luting cement, which joins the components.

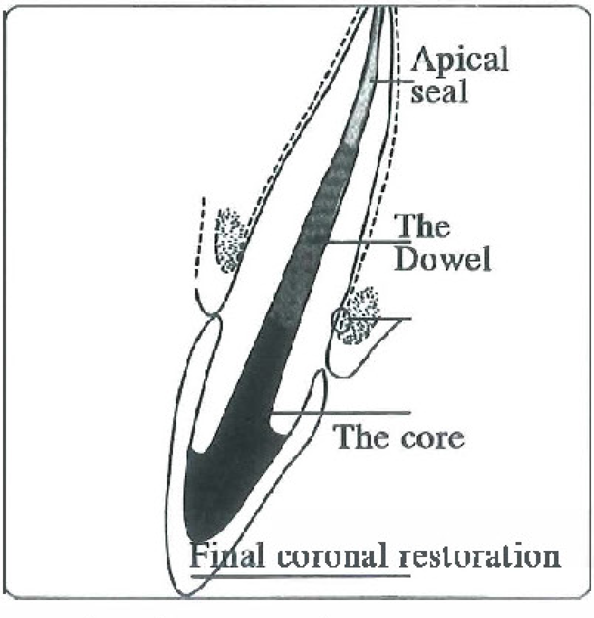


Fig. 5. Final form of the fully restored tooth.

IV. TREATMENT OPTIONS:

◊ Restorative treatment ranges from just sealing of the access cavity in intact teeth to the use of dowel, core, and coronal restoration in extensively damaged teeth.

- Only core.
- Post and core.
- Core and full coverage.

- Post, core and full coverage .
- Endocrown.

Teeth type	Anterior teeth	Posterior teeth
Characteristics	- Large pulp space. Limited tooth structure especially at the cervical area. - Subject to great lateral and shear forces. - Esthetics.	- Reasonable amount of tooth structure especially molars. - Cusp deflection. - Premolars are subject to large lateral forces than molars. - Molars are subject to vertical forces
Treatment Options	- **Intact marginal ridges and incisal edges** ------ dentin bonded composite. - **Discoloration,** -------- nonvital bleaching or with direct or nondirect veneers. - **Large proximal caries, restorations undermining the marginal ridges or fractured incisal edge** ---- Post, core and crown. - **If an anterior endodontically treated tooth is to receive a crown,** a post is a must (lateral forces).	- **Posterior teeth with two intact marginal ridges** ---------------- resin bonded composite core (in most cases). - **Posterior teeth with ½ tooth structure** can be restored with endocrowns (ceramic or composite) - **Premolars** require post / core and cusp coverage (lateral forces). - **Molars require** cusp coverage with or without post placement.

Chapter review Questions

1. Describe the effect of endodontic treatment on the tooth.
2. Before any therapy is initiated, the endodontically treated tooth must be thoroughly evaluated to ensure treatment success. Discuss.
3. What are the factors considered in post and core design ?
4. What are the treatment options for an anterior tooth with root canal treatment?

References

- Hargreaves KM, Cohen S. Pathways of the Pulp. 11th ed. Elsevier. 2016.
- Ingle JL, Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- Textbook of Endodontics: Garg N, Garg A. 1st edition 2007 JAYPEE
- Lin C, ChangY, Pai C. Evaluation of failure risks in ceramic restorations for endodontically treated premolar with MOD preparation. Dental materials 2011; 27 (5): 431-438.
- Mannocci F, Cowie J. Restoration of endodontically treated teeth. Br Dent J. 2014 Mar;216(6):341-6.

30

Bleaching of Discolored Teeth

Angie G. Ghoneim

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify the cause and nature of tooth discoloration.
2. Describe means of preventing coronal discoloration.
3. Differentiate between dentin and enamel discolorations.
4. Select the bleaching agent and technique according to the cause of discoloration.
5. Describe each step of the internal "walking bleach" technique.
6. Describe different types of vital bleaching techniques.

The postgraduate student should be able to:

1. Interpret the effect of intracoronal bleaching agents on tooth structure.
2. Analyze endodontically related discolorations.
3. Appraise the effect of different endodontic sealers on the outcome of bleaching.
4. Criticize debates related to the different types of vital and non-vital bleaching techniques.
5. Outline factors affecting bleaching
6. Assess the potential adverse effects of internal bleaching and their prevention.

Chapter Outline

Tooth discoloration is defined as any change in the hue, color, or translucency of a tooth that may be induced by intrinsic stains incorporated in tooth structures and or extrinsic stains deposited on tooth surfaces.

Discoloration of anterior teeth is cosmetic problem that is often significant enough to induce patients to seek corrective measures. Although restorative methods are available, such as crowns and veneers, frequently discoloration can be corrected totally or partially by bleaching.

Bleaching procedures are more conservative than restorative methods, relatively simple to perform and less expensive. Procedures may be internal (within the pulp chamber) or external (on the enamel surface). Before attempting to correct discoloration, a diagnosis must be made (determine the cause and location of the stain), treatment planning must be done (external or internal technique), and a prognosis assessed (short or long term success).

Causes of discoloration

Tooth discoloration can occur during or after enamel and dentin formation. Some stains appear as surface stains after eruption and others are the results of dental procedures. Hence, causes of discoloration can be classified into two main groups. First group, natural (acquired) stains which may be on the surface or incorporated into tooth. Second group, iatrogenic stains, which result from dental procedures.

I- Natural or acquired discolorations

1. Pulp necrosis

Bacterial, mechanical or chemical irritation of the pulp may result in necrosis. Tissue disintegration products are then released; these colored compounds may permeate the dentinal tubules and stain the surrounding dentin. The degree of discoloration is directly related to how long the pulp has been necrotic. This type of discoloration can be bleached internally.

2. Intrapulpal hemorrhage

Generally, intrapulpal hemorrhage is associated with an impact injury to a tooth, which results in disrupted coronal blood vessels, hemorrhage, and lysis of the red blood cells. Blood disintegration products, presumably as iron sulfides, permeate dentinal tubules to stain surrounding dentin. If the pulp becomes necrotic, the discoloration usually remains. If the pulp survives, the discoloration may resolve and the tooth regains its original shade. Internal bleaching after intrapulpal hemorrhage is usually successful.

3. Calcific metamorphosis

Calcific metamorphosis is extensive formation of irregular secondary dentin in the pulp chamber or on canal walls. This phenomenon usually follows an impact injury that did not result in pulp necrosis. There is temporary disruption of the blood supply with destruction of odontoblasts. These are replaced by undifferentiated mesenchymal cells that rapidly form irregular dentin on the walls of the pulp space. As a result, the crowns of these teeth gradually decrease in translucency and acquire a yellowish or yellowish-brown discoloration. The pulp usually remains vital and uninflamed. If the patient desires color correction, root canal treatment is performed and internal bleaching is done.

4. Age

Tooth color tends to become progressively darker with age, which is a physiological change resulting from dentin apposition, thinning of the enamel, and optical changes. Cumulative extrinsic stains from food and beverages also contribute to this type of tooth discoloration. Extra oral bleaching can be successfully applied for such patients.

5. Developmental defects

Discoloration may result from developmental defects or from substances incorporated into enamel or dentin during tooth formation.

Defects in tooth formation: defects in tooth formation are confined to the enamel and are either hypocalcific or hypoplastic. *Enamel hypocalcification* is common, appearing as a

distinct brownish or whitish area, often on the facial aspect of a crown. The enamel is well formed and intact on the surface and feels hard to the explorer. *Enamel hypoplasia* differs from hypocalcification in that enamel in the former is defective and porous. This condition may be hereditary (amelogensis imperfecta) or may result from environmental factors (infections, tumors or trauma). In the hereditary type, both the deciduous and permanent dentition are involved. Defects caused by environmental factors involve one or several teeth and are detected in both dentitions. Presumably during tooth formation the matrix is altered and does not totally or properly mineralize. The porous enamel readily acquires stains from the oral cavity.

Endemic fluorosis (mottled tooth): Ingestion of excessive amounts of fluoride during tooth formation produces defects in mineralized structures, particularly enamel, with resultant hypoplasia. The teeth are not discolored on eruption but may appear chalky. Their surface, however is porous and gradually absorbs stains from chemicals in the oral cavity. Discoloration is usually bilaterally symmetric. Because the stain is in porous enamel, such teeth are bleached externally.

Systemic drugs: administration or ingestion of certain drugs or chemicals during tooth formation may cause discoloration. The most common staining of this type follows tetracycline ingestion in children Fig. (1). Discoloration is bilateral affecting multiple teeth in both arches and may range from yellow through brownish to dark gray depending on the amount, frequency, type of tetracycline and patient's age during its administration. Tetracycline binds to calcium, which is then incorporated into hydroxyapatite crystal in both enamel and dentin. Chronic sun exposure of teeth with the incorporated drugs may cause formation of reddish-purple tetracycline oxidation by products, resulting in further discoloration of permanent teeth. Two approaches can be used to treat tetracycline discoloration: The first, involves extra coronal bleaching and is limited to lighter yellowish discoloration. The second is root canal treatment followed by internal bleaching and is useful for all degrees of discoloration.

Fig 1. Characteristic grayish discoloration and banding of tetracycline discoloration.

Blood dyscrasias and other factors:

Various systemic conditions may cause massive lysis of red blood cells. If this occurs in the pulp at an early age, blood disintegration products are incorporated into and stain the forming dentin.

Erythroblastosis fetalis is characterized by severe discoloration of the primary teeth. This disease in the fetus or newborn results from RH incompatibility factor, which lead to massive systemic lysis of erythrocytes. Large amounts of hemosiderin pigment stain the forming dentin in primary teeth. Such condition is not correctable by bleaching.

Amelogenesis imperfecta: may result in yellow or brown discoloration.

Dentinogenesis imperfecta: can cause brownish violet, yellowish, or gray discoloration. These conditions are also not correctable by bleaching and need restorative means.

High fever during tooth formation may result in linear defined enamel hypoplasia, that give rise to banding type surface discoloration.

Porphyria, a metabolic disease may cause deciduous and permanent teeth to show a red or brownish discoloration.

Thalassemia and sickle cell anemia may cause intrinsic bluish, brown or green discoloration.

II- Iatrogenic discoloration

Discoloration due to various chemicals and substances used in dentistry are usually avoidable. Many of these are difficult to correct by bleaching.

1. Endodontically related stains:

Remnants of pulpal tissue: pulp fragments, remaining in the crown, usually in the pulp horns, may cause gradual discoloration. Pulp horns must be opened up and exposed during access to ensure removal of pulpal remnant and to prevent retention of sealer at a later stage.

Various materials used during root canal treatment can cause coronal tooth discoloration if they are left in the crown of the tooth during or after treatment (Tables 1-3).

Root canal irrigants: sodium hypochlorite, at varying concentrations, is the most common irrigant used alone or in combination with other solutions to enhance antimicrobial activity and to aid in removing smear layer. The combination of NaOCL with other adjunct irrigating solutions has been found to cause marked tooth discoloration (Table 1).

Table (1) Tooth discoloration associated with root canal irrigants

Irrigating solutions	Type of discoloration
NaOCl + Chlorhexidine CHX	Light orange - dark brown (acc to conc.)
MTAD+ NaOCl (different conc.)	Brown (NaOCl final rinse)
1.3% NaOCl– MTAD	Red-purple (MTAD final rinse)
17% EDTA+ 1%CHX	Pink precipitate (CHX final rinse)

Intracanal medicaments: several intracanal medicaments can cause internal staining of dentin. Phenolics or iodoform–based medicaments, which are commonly sealed into teeth, are in direct contact with dentin, sometimes for long periods, allowing for their penetration and oxidization with subsequent dentin discoloration (Table 2).

Table (2) Tooth discoloration associated with intra-canal medicaments

Intra-canal medicaments	Type of discoloration
Formocresol	Marked discoloration
Iodoform-based	Yellow-yellow brown
Triple antibiotic paste	Blue greyish
Ledermix paste	Grey-brown
UltraCal XS	Yellow

Obturating materials: this is a frequent cause of single tooth discoloration. Incomplete removal of obturating materials and sealer remnants from the pulp chamber, mainly those containing metallic components, often result in dark staining. Removing all materials to a level just cervical to the gingival margin can prevent such stains often result in dark staining (Table 3).

Table (3) Tooth discoloration associated with root canal sealers

Root canal sealer	Type of discolouration
Grossman's ZnO/E	Orange -red
AH 26	Grey - Black
Endomethasone	Orange -red
Tubli Seal	Mild pink to orange -red
Diaket	Mild pink
Sealapex	Light grey
MTA	Grey

2. Coronal restoration

Metallic restorations: amalgam is the worst offender because its dark colored elements may turn dentin dark gray. If used to restore a lingual access preparation, amalgam often discolors the crown. In addition to the inherent dark, metal-

lic color of an amalgam restoration, amalgam degrades over time and corrosion products can cause tooth discoloration. Such stains are difficult to bleach and tend to re-discolor with time.

Composite restorations: microleakage of composites causes staining open margins which may permit chemicals to penetrate between the restoration and tooth structure to stain the underlying dentin.

Bleaching materials

Bleaching chemicals may act as either oxidizing or reducing agents. Most bleaching agents are oxidizers. Commonly used agents are solutions of hydrogen peroxide of different strengths; sodium perborate and carbamide peroxide. Sodium perborate and carbamide peroxide are chemical compounds that are gradually degraded to release low levels of hydrogen peroxide. Hydrogen peroxide and carbamide peroxide are mainly indicated for external bleaching, whereas sodium perborate is used for internal bleaching.

Hydrogen peroxide (H_2O_2): is a powerful oxidizer that is available in various strengths, but a 30% to 35% stabilized solution (Superoxol, Perhydrol) is the most common. These high-concentration solutions must be handled with care because they are unstable, lose oxygen quickly and may explode unless they are refrigerated and kept in a dark container. Also, these are caustic chemicals and will burn tissue on contact.

Sodium perborate:is available in powder form or in various commercial proprietary combinations. It is stable when dry but in the presence of acid, warm air, or water it decomposes to form sodium metaborate, hydrogen peroxide and nascent oxygen. Sodium perborate is more easily controlled and is safer than concentrated H_2O_2.

Carbamide peroxide:also known as urea hydrogen peroxide is available in concentrations varying between 3 and 15%. Carbamide peroxide has been associated with varying degrees of damage to teeth and surrounding mucosa. They may adversely affect the bond strength of composite resins and their marginal seal.

Bleaching mechanism

The mechanism of tooth bleaching remain unclear at present; however it is generally believed that free radicals produced by H_2O_2 may be responsible for bleaching effects. H_2O_2 diffuses through the enamel and dentin, producing free radicals that react with pigment molecules breaking their double bonds. The change in pigment molecule configuration and or size may result in changes in their optical properties and consequently the perception of a lighter color by human eyes.

Bleaching techniques

1. Intracoronal bleaching techniques

The methods most commonly employed to bleach endodontically treated teeth are the thermocatalytic technique, ultraviolet photo-oxidation technique and the walking bleach technique. Walking bleach is preferred because it requires the least chair time and is more comfortable and safer for the patient.

Internal bleaching may be performed at various intervals following root canal treatment. However, the walking bleach technique may be performed at the same appointment as the obturation. In fact the shorter discoloration period tends to improve the chances for successful bleaching as well as reduces the likehood of re-discoloration.

Indications:

1. Discolorations of pulp chamber origin.
2. Dentin discolorations.
3. Stains not amenable to external bleaching.

Contraindications:

1. Superficial enamel stains.
2. Defective enamel formations.
3. Severe dentin loss.
4. Carious or discolored composite.

Thermocatalytic technique

This technique involves placement of the oxidizing chemical, generally 30% -35% H_2O_2 (Superoxol) into the pulp chamber followed by heat application. Heat is supplied by heat lamps, flamed instruments, or electrical heating devices, which are manufactured specifically to bleach teeth. Intermittent treatment with cooling breaks is preferred over a continuous session.

Ultraviolet photo-oxidation

In this technique ultraviolet light is applied to the labial surface of the tooth to be bleached. A 30% to 35% H_2O_2 solution is placed in the chamber on a cotton pellet followed by a 2-minute exposure to ultraviolet light. Supposedly, this causes the release of oxygen similar to that seen in the thermocatalytic bleaching technique.

Walking bleach

Nutting and Poe first coined the term walking bleach in 1961 referring to the bleaching action occurring between patient's visits. It involves the following steps Fig. (2):

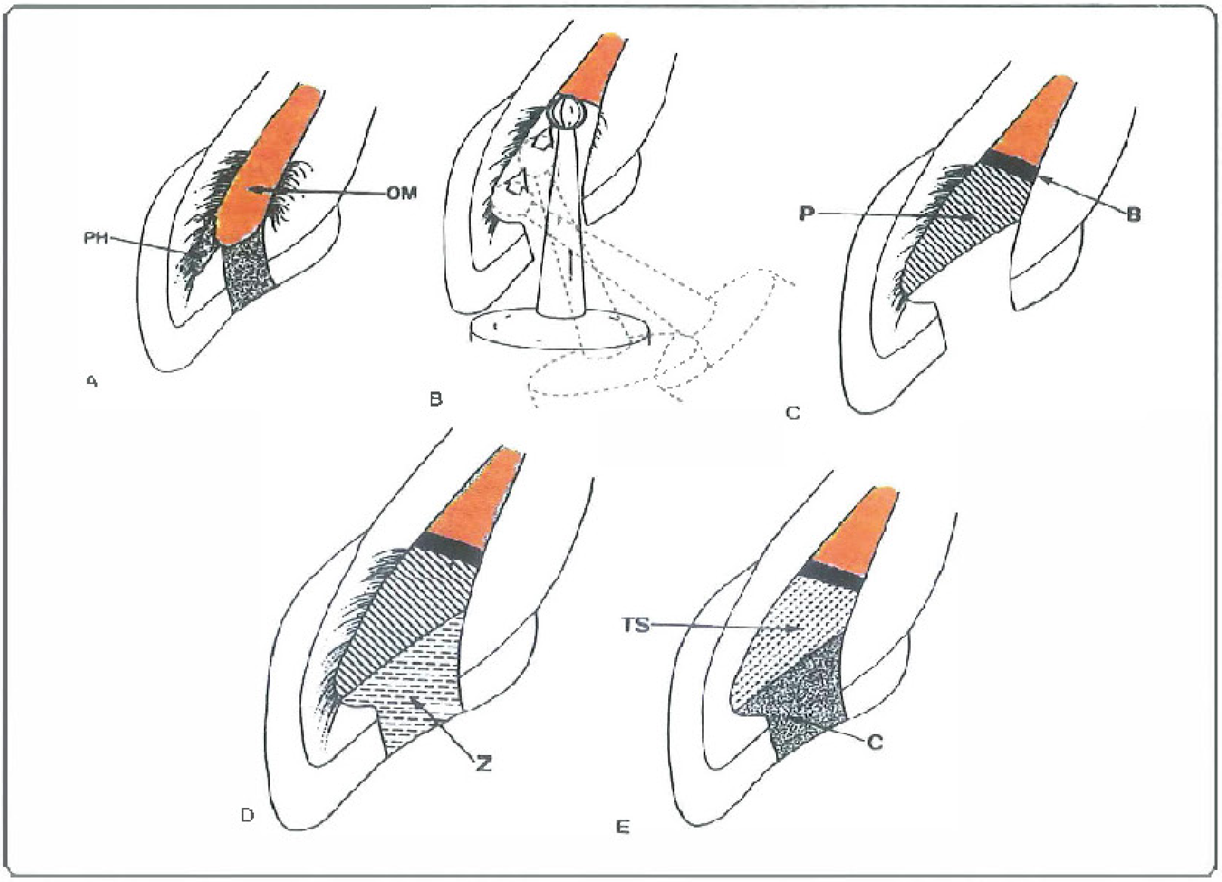


Fig 2. Walking bleach, A, Internal staining of dentin caused by remnants of obturating materials (OM) in the chamber as well as by materials and tissue debris in pulp horns (PH). B, Coronal restoration is removed completely. C, A protective cement base (B) is placed over the gutta-pecha. A paste (P) of sodium perborate and hydrogen peroxide is placed. D, A thick mix of temporay cement (Z) seals access. E, At a subsequent appointment when the desired shade reached, a permanent cement is placed (TS) at the pulp chamber and composite resin (C) to seal of the access.

1. Radiographs are made to assess the status of the periapical tissues and the quality of root canal treatment. Treatment failure or questionable obturation requires retreatment prior to bleaching.

2. The quality and shade of any coronal restoration present are assessed; if defective the restoration must be replaced before bleaching procedures.

3. Tooth color is evaluated with a shade guide and clinical photographs are taken at the beginning of and throughout the procedures. These provide a point of reference for future comparison by both dentist and patient.

4. The tooth is isolated with a rubber dam (interproximal wedges and ligatures may also be used). If Superoxol is used protective cream (orabase or cocoa butter) must be applied to the gingival tissues prior to dam placement. The restorative material is removed from the access cavity. Refinement of the access and removal of all old obturating materials from the chamber comprise the most important stage in the bleaching process. The dentist should check carefully that pulp horns or other hidden areas are properly exposed. If the chamber has been totally filled with composite, it must be removed completely to allow the bleaching agent to contact and penetrate the dentin

5. (***Optional***) this step may be necessary if the stain seems to be metallic or if on the second or third appointment bleaching only does not seem to be sufficient. A thin layer of stained dentin is carefully removed toward the facial aspect of the chamber with a round bur in a slow-speed handpiece. This will remove much of the discoloration (which is concentrated in the pulpal surface area). It may also open the dentinal tubules for better penetration by the chemicals.

6. All materials should be removed to a level just below the gingival margin. Appropriate solvents (such as chloroform or xylol on a cotton pellet) are used to dissolve remnants of the common sealers.

7. A sufficient layer of a protective white cement barrier (such as Cavit at least 2mm thick) is applied on the obturating material. This is essential to minimize leakage of bleaching agents.

8. The walking bleach paste is prepared by mixing sodium perborate and an inert liquid such as water, saline, or anesthetic solution. With a plastic instrument, the pulp chamber is packed with the paste. Excess liquid is removed by tamping with a cotton pellet. This also compresses the paste.

9. Excess oxidizing paste is removed from undercuts in the pulp horn and gingival area with an explorer, then thick mix of zinc oxide eugenol (preferably) IRM is applied directly against the paste and into the undercuts. The temporary filling is packed carefully to a thickness of at least 3mm to ensure a good seal.

10. The patient is rescheduled approximately 2weeks later and the procedure is repeated. It is commonly believed that over bleaching is desirable because of probable future re-discoloration.

Final restoration

The pulp chamber and the access cavity should be restored with a light shade, light cured, acid-etched composite resin. Light curing from the labial surface (to reduce shrinkage) and placing white cement beneath the composite is recommended. The use of catalase has been proposed for fast elimination of residual peroxides from the access cavity.

Complications

External cervical root resorption

Internal bleaching may induce external cervical root resorption. This is probably caused by high concentrated oxidizing agent, which

diffuses via unprotected dentinal tubules and cementum defects and causes necrosis of the cementum, inflammation of the periodontal ligament with subsequent root resorption. The process may be enhanced if heat is applied.

Damage to the restoration

Bleaching with hydrogen peroxide may affect bonding of composite resins to tooth structure. It is recommended to subject the tooth to catalase treatment for three minutes, which will remove all residual hydrogen peroxide.

Chemical burns

Superoxol (30% hydrogen peroxide) is highly caustic and causes chemical burns and sloughing of the gingiva. When this strong chemical is used, the soft tissues should be coated with Vaseline, Orabase, or cocoa butter.

2. Extracoronal bleaching techniques

In this technique the oxidizer is applied to the enamel surface of a tooth with vital pulp. Application of bleaching agents on relatively impermeable enamel has little chance of reaching the stain.

Indications:

1- Light enamel discolorations.
2- Mild tetracycline stains.
3- Endemic fluorosis stains .
4- Age-related discoloration.

Contraindications:

1- Severe dark discoloration.
2- Severe enamel loss.
3- Proximity of pulp horns.
4- Hypersensitive teeth.
5- Caries, large, or poor restoration.

Vital bleaching technique:

- In-office extracoronal bleaching.
- At-home extracoronal bleaching (mouth guard bleaching).

In –office extracoronal bleaching:

Several materials and clinical procedures are available for in-office extracoronal bleaching, also called chair-side bleaching or power bleaching. In-office extracoronal bleaching may be performed using a bleaching gel (with 25% to 38% H_2O_2) alone or a gel with a light. Various light sources can be used namely; laser (argon, CO_2), halogen, plasma arc, or light-emitting diodes (LED). The wavelength may range from high ultraviolet spectra, low visible blue light spectra, to invisible infrared spectra such as CO_2 laser. The light exposure is intended to enhance the bleaching efficacy by activating the bleaching gel, either through a specific catalyst or heat, to promote the decomposition process of H_2O_2 on the enamel surface.

At- home bleaching (Mouth guard):

The mouth guard bleaching technique (home bleaching) is generally used for mild discolorations. Numerous products are available for home use. Most are composed of either 1.5%-10% hydrogen peroxide or 10%-15% carbamide peroxide.

Technique:

1) An alginate impression is made of the arch to be treated. Two layers of die relief are placed on the buccal aspects of the cast teeth to form a small reservoir for the bleaching agent.
2) The mouth guard is inserted to insure proper fit. The guard is removed and the bleaching agent is applied in the labial aspect of each tooth to be bleached. The mouth guard is then re-inserted over the teeth and excess bleaching agent removed.
3) The patient is familiarized with the use of the bleaching agent and with the method of wearing the guard. The procedure is usually performed for 3 to 4 hours/day. Some practitioners recommend wearing the guard during sleeping for better long-term aesthetic results. The treatment continues for 4 to 24 weeks. The patient is recalled every 2 weeks to monitor lightening or complications.

Complications:

Postoperative pain:

A common postoperative problem is pulpal pain characterized by intermittent shooting pain, which occur immediately after bleaching and last for about 24 to 48 hours. Long-term sensitivity to cold may also occur. This complication can be reduced by shorter bleaching periods and using lower temperature. Topical fluoride treatments and desensitizing toothpaste can alleviate these symptoms.

Pulpal damage:

Extracoronal bleaching with hydrogen peroxide and heat has been sometimes associated with some pulpal damage especially in the presence of deep caries or exposed dentin. Defective restorations must be replaced before bleaching. Teeth with large restorations should not be bleached.

Mucosal damage:

Bleaching agents are caustic and if they come in contact with oral mucosa may cause peroxide-induced tissue damage. Ulceration and sloughing of the mucosa are caused by oxygen gas bubbles in the tissue, which appear white. Treatment is by extensive water rinses until the whiteness is reduced. Application of protective ointment before bleaching can prevent such complication.

Chapter Review Questions

1. Discuss causes for acquired discoloration.
2. Discuss causes for iatrogenic discoloration.
3. Describe the steps of the internal "walking bleach" technique
4. Discuss the bleaching mechanism and different bleaching agents.

References

- Ingle JI., Bakland LK, Baumgartner JC. Ingle's Endodontics 6. 6th ed. BC Decker Inc.,2008.
- Walton RE, Torabinejad M. Principles and Practice of Endodontics 4th ed. W.B. Saunders Company. 2009.
- Bizhang M, Heiden A, Blunck U, Zimmer S, Seemann R, Roulet JF. Intracoronal bleaching of discolored non-vital teeth. Oper Dent. 2003 Jul-Aug;28(4):334-40.
- Zimmerli B, Jeger F, Lussi A. Bleaching of nonvital teeth. A clinically relevant literature review. Schweiz Monatsschr Zahnmed. 2010;120(4):306-20.
- Patil AG, Hiremath V, Kumar RS, Sheetal A, Nagaral S. Bleaching of a non-vital anterior tooth to remove the intrinsic discoloration. J Nat Sci Biol Med, 2014;5(2) 475-479.

31 Geriatric Endodontics

Sieza Yakoub
Khaled M. Ezzat

Intended Learning objectives

After reading this chapter, the student should be able to

1. Identify those biologic aspectsin the elderly patient that are similar to and different from those in the younger patient.
2. Describe complications presented by the medically compromised older patients.
3. Describe each process of diagnosis and treatment planning in the elderly patient.
4. Discuss why there are differences and what those differences are when root canal treatment is performed.
5. Recognize the complications of endodontic surgery.
6. Select the appropriate restoration after root canal treatment.

Postgraduate students should be able to

1. Judge the biological aspects
2. Manage the complications presented by medically complex patient
3. Design the appropriate restoration after root canal treatment

Chapter Outline

The purpose of this chapter is to discuss the effect of aging on the diagnosis of pulpal and periapical disease and successful root canal treatment. The quality of life for older patients can by significantly improved by saving teeth through endodontic treatment and can have a large and impressive value to overall dental, physical, and mental health.

Negative social attitudes toward older adults tend to carry over into their care. Older patients are in danger of being dismissed as hopeless or not worth the effort. At times, clinicians shy away from providing care for seniors because of the perceived difficulty of cost of certain treatment procedures or because of complicated medical conditions. Clinicians sometimes consider older patients less able to pay for treatment because of their age and appearance. However, most older adults engage in normal activity and can recognize and afford the value of good dentistry.

The needs, expectations, desires, and demands of older people may exceed those of any age group, and the gratitude shown by older patients is among the most satisfying of professional experiences. The desire for root canal treatment among aging patients has increased considerably in recent years. Older patients are aware that treatment can by performed comfortably and that age is not a factor in predicting success.

Obtaining informed consent that root canal treatment is alternative to the trauma of extraction and the cost of replacement.

MEDICAL HISTORY

It is important to focus on those factors that will truly indicate the risks undertaken in treating the older patient. Clinicians must recognize that the biologic or functional age of an individual is far more important than chronological age.

A medical history should by taken before the patient is brought into the treatment room, and a standardized form should be used to identify any disease or therapy that would alter treatment or its outcome.

In general, aging causes dramatic changes to the cardiovascular, respiratory, and central nervous systems (CNS) that result in most drug therapy needs. However, the dealing in renal and liver function in older patients should also be considered when predicting behavior and interaction of drugs (e.g., anesthetics, analgesics, antibiotics) that may be used in dental treatment.

The review of the patients' medical history is the first opportunity for the dentist to talk with the patient. The time and consideration taken at the outset will set the tone for the entire treatment process. This first impression should reflect a warm, caring practitioner, who is highly trained and able to help patients with complex treatments. Some older patients may need assistance in filling out the forms and may not by fully aware of their conditions or history.

Consultation with the patient's family, guardian, or physician may be necessary to complete the history; however, the dentist is ultimately responsible for the treatment.

An updated history, including information on compliance with any prescribed treatment and sensitivity to medications, must by obtained at each visit and reviewed. In general, older adults use more drugs than younger patients, and most of these medications are potentially important to the dentist. The physicians Desk Reference should be consulted and any precaution or side effect of medication noted.

Although geriatric patients are usually knowledgeable about their medical history, some may not understand the implications of their medical conditions in relation to dentistry or may be reluctant to let the clinician into their confidence. Their perceptions of their illnesses may not be accurate, so any clue to a patient's conditions should be investigated.

Symptoms of undiagnosed illnesses may present the dentist with a screening opportunity that can disclose a condition that might otherwise go untreated or lead to an emergency. Management of medical emergencies in the dental office is best directed toward prevention rather than treatment.

Chief Complaint

Most patients who are experiencing dental pain have a pulpal or periapical problem that requires root canal treatment or extraction. Dental needs are often manifested initially in the form of a complaint, which usually contains the information necessary to make a diagnosis. The diagnostic process is directed toward determining whether pulpal or periapical disease is present, whether palliative or root canal therapy is indicated, the vitality of the pulp, and which tooth is the source of pain.

The clinician should, without leading, allow the patient to explain the problem in his or her own way.

This gives the examiner an opportunity to observe the patient's level of dental knowledge and ability to communicate. Visual and auditory handicaps may become evident at this time.

The effect of the "focal infection" theory is still evident when other aches and pains cannot be adequately explained and loss of teeth is accepted as inevitable. The best patients are those who have already had successful endodontic treatment. Older patients are more likely to have already had root canal treatment and have a more realistic perception about treatment comfort.

Most geriatric patients do not complain readily about signs or symptoms of pulpal and periapical disease and may consider them to be minor compared with other health concerns.

Pain associated with vital pulps (i.e., referred pain; pain caused by heat, cold, or sweets) seems to be reduced with age, and severity seems to diminish over time. Heat sensitivity that occurs as the only symptom suggests a reduced pulp volume such as that occurring in the older pulps.

Pulpal-healing capacity is also reduced, and necrosis may occur quickly after microbial invasion, again with reduced symptoms.

Although complaints are fewer, they are usually more conclusive evidence of disease. The complaint should isolate the problem sufficiently to allow the clinician to take a periapical radiograph before proceeding. Studying radiographs before an examination can prejudice rather than focus attention; accordingly, they should be reviewed after the clinical examination has been completed.

DENTAL HISTORY

The clinician should search patients' records and explore their memories to determine the history of involved teeth or surrounding areas. The history may be as obvious as a recent pulp exposure and restoration, or it may be as subtle as a routine crown preparation 15 or 20 years ago. Any history of pain before or after treatments may establish the beginning of a degenerative process. Subclinical injuries caused by repeated episodes of decay and its treatment may accumulate and approach a clinically significant threshold that can be later exceeded after additional routine procedures. Multiple restorations on the same tooth are common.

Subjective Symptoms

The examiner can pursue responses to questions about the patient's complaint, the stimulus or irritant that causes pain, the nature of the pain, and its relationship to the stimulus or irritant. This information is most useful in determining whether the source is pulpal disease, whether inflammation or infection has extended to the apical tissues, and whether these problems are reversible. Thus the dentist can determine what types of tests are necessary to confirm findings or suspicions.

Objective Sings

The intraoral and extraoral clinical examination provide valuable first-hand information about disease and previous treatment. The overall oral condition should not be over-looked while centering on the patient's complaint, and all abnormal conditions should be recorded and investigated.

Clinical considerations in treating old patients.

1. Exposures to factors that contribute to oral cancers accumulate with age, and many systemic diseases may initially manifest prodromal oral sings or symptoms.
2. Missing teeth contribute to reduced functional ability. The resultant loss of chewing

efficiency leads to a higher carbohydrate diet of softer, more cariogenic foods. Increased sugar intake to compensate for loss of taste and xerostomia are also factors in the renewed susceptibility to decay.

3. Gingival recession, which creates sensitivity and is hard to control, exposes cementum and dentin that are less resistant to decay.
4. The removal of root caries is irritating to the pulp and often results in pulp exposures or reparative dentin formation that affect the negotiation of the canal, should root canal treatment later by needed.
5. Asymptomatic pulp exposures on one root surface of a multirooted tooth can result in the uncommon clinical situation of the presence of both vital and nonvital pulp tissues in the same tooth.
6. Interproximal root caries is difficult to restore, and restoration failure as a result of continued decay is common.
7. Attrition, abrasion, and erosion also expose dentin through a slower process that allows the pulp to respond with dentinal sclerosis and reparative dentin.
8. Secondary dentin formation occurs throughout life and may eventually result in almost complete pulp obliteration. In maxillary anterior teeth, the secondary dentin is formed on the lingual wall of the pulp chamber; in molar teeth the greatest deposition occurs on the floor of the chamber. Although this pulp may appear to recede, small pulpal remnants can remain or leave a less calcific tract that may lead to a pulp exposure.
9. In general, canal and chamber volume is inversely proportional to age: as age increases, canal size decreases. Reparative dentin resulting from restorative procedures, trauma, attrition, and recurrent caries also contributes to diminution of canal and chamber size. The calcification process associated with aging appears clinically to be of a more linear type than that which occurs in a younger tooth in response to caries, pulpotomy, or trauma.
10. In addition, the cementodentinal junction (CDJ) moves farther from the radiographic apex with continued cementum deposition .The thickness of young apical cementum is 100 to 200 m and increases with age to two or three times that thickness.
11. Advancing age, decreasing tubular permeability. Lateral and accessory canals can calcify, thus decreasing their clinical significance.
12. The compensating bite produced by missing and tilted teeth (or attrition) can cause temporomandibular joint (TMJ) dysfunction or loss of vertical dimension. The authors have observed diminished eruptive forces with age, reducing the amount of mesial drift and super eruption. Any limitation in opening reduces available working time and the space needed for instrumentation.
13. The presence of multiple restorations indicates a history of repeated insults and an accumulation of cavity walls is a major cause of pulpal injury.
14. Violating principles of cavity design combined with the loss of resiliency that results from a reduced organic component in the dentin to increase susceptibility to cracks and cuspal fractures.
15. Many cracks or craze lines may be evident as a result of staining, but they do not indicate dentin penetration or pulp exposure.
16. Periodontal disease may be the principal problem for older patients. The relationship between pulpal and periodontal disease can be expected to be more significant with age. Retention of teeth alone demonstrates some resistance to periodontal disease. Narrow, bony-walled pockets associated with nonvital pulps are usually sinus tracts, but they can be resistant to root canal therapy alone when, with time, they become chronic periodontal pockets.
17. Periodontal treatment can produce root sensitivity, disease, and pulp death. The more increase in incidence and severity of periodontal disease with age increases the need for combined therapy. The chronic

nature of pulp disease demonstrated with sinus tracts can often be manifested in a periodontal pocket.

18. The presence of a sinus tract reduces the risk of interappointment or postoperative pain, although drainage may follow canal debridement or filling.

19. The reduced neural and vascular components of aged pulps, the overall reduced pulp volume, and the change in character of the ground substance create an environment that responds differently to both stimuli and irritants than that of younger pulps. Consequently, the response to stimuli may be weaker than in the more highly innervated younger pulp.

20. No correlation exists between the degree of response to electric pulp testing and the degree of inflammation. A test cavity is generally less useful as the test of last resort because of reduced dentin innervation. Vital pulps can sometimes be exposed and even negotiated with a file with minimal pain.

21. Discoloration of single teeth may indicate pulp death, but this is a less likely cause of discoloration with advanced age. Dentin thickness is greater and the tubules are less permeable to blood or breakdown products from the pulp. Dentin deposition produces a yellow, opaque color that would indicate progressive calcification in a younger pulp; however, this is common in older teeth.

Radiographs

Indications for and techniques of taking radiographs do not differ much among adult age groups. However, several physiologic, anatomic changes can significantly affect their interpretation. Film placement may be adversely affected by tori but can be assisted by the apical position of muscle attachments that increase the depth of the vestibule.

Older patients may be less capable of assisting in film placement, and holders that secure the position should be considered.

1. The presence of tori, exostoses, and denser bone may require increased exposure times for proper diagnostic contrast. The subjective nature of interpretation can be reduced with correct processing, proper illumination, and magnification.

2. The periapical area must be included in the diagnostic radiograph, which should be studied from the crown toward the apex. Angled radiographs should be ordered only after the original diagnostic radiograph suggests that more information is needed for diagnosis or to determine the degree of difficulty of treatment. Radio Visio Graphy (RVG) may be more useful than conventional radiography in detecting early bone changes.

3. In older patients, pulp recession is accelerated by reparative dentin and complicated by pulp stones and dystrophic calcification. Deep proximal or root decay and restorations may cause calcification between the observable chamber and root canal.

4. The depth of the chamber should be measured from the occlusal surface and its mesiodistal position noted.

5. Receding pulp horns that are apparent on a radiograph may remain microscopically much higher. Deep restorations or extensive occlusal crown reduction may produce pulp exposures that were not expected. The axial inclination of crowns may not correlate with the clinical observation when tilted teeth have been crowned or become abutments for fixed or removable appliances. Access to the root canals is the most limiting condition in root canal treatment of older patients.

6 Canals should be examined for their number, size, shape, and curvature. Comparisons to adjacent teeth should be made. Small canals are the rule in older patients. A midroot disappearance of a detectable canal may indicate bifurcation rather than calcification. Canals calcify evenly throughout their length unless an irritant (e.g., decay, restoration, cervical abrasion) has separated the chamber from the root canal.

7. Root end fillings during apicectomies (more common during retreatment of older patients) indicate missed canals and roots as a common cause of failure.
8. The lamina dura should be examined in its entirety and anatomic landmarks distinguished from periapical radiolucencies and radiopacities.
9. The incidence of some odontogenic and nonodontogenic cysts and tumors characteristically increases with age, and this should be considered when vitality test do not correlate with radiographic findings. However, the incidence of osteosclerosis and condensing osteitis decrease with age.
10. Resorption associated with chronic apical periodontitis may significantly alter the shape of the apex and the anatomy of the foramen through inflammatory osteoclastic activity.
11. The narrowest point in the canal may be difficult to determine; it is positioned farther from the radiographic apex because of continued cementum formation and may be demonstrated by a canal or foramen that appears to end or exit short of the radiographic apex, and hypercementosis may completely obscure the apical anatomy.

TREATMENT PLAN

A clinical judgment can be made, based on the patient's complaint, history, signs, symptoms, testing, and radiographs, as to the vitality of the pulp and the presence or absence of periapical pathologic conditions. This classification has not been shown to be a factor in predicting success, interappointment or postoperative pain, or the number of visits necessary to complete treatment when the objectives of cleaning, shaping, and filling are clearly understood and consistently met. Of great clinical significance in treatment procedures is the assessment of pulp status to determine the depth of anesthesia necessary to perform the treatment comfortably.

One appointment procedure offers obvious advantages to older patients. The length of a dental appointment does not usually cause inconvenience, as may more numerous appointments, especially if a patient must rely on another person for transportation or needs physical assistance to get into the office.

Root canal treatment as a restorative expediency on teeth with normal pulps must be considered when cusps have fractured or when supererupted or partial abutments, rest seats, or overdentures require significant tooth reduction.

Because of a reduced blood supply, pulp capping is not as successful in older teeth as in younger ones, therefore it is not recommended.

CONSULTATION AND CONSENT

Determining the patient's desires is an important as determining his or her needs, and it is required in obtaining informed consent. Priorities in treating pain and infection to properly and anesthetically restore teeth to health and function should be unaffected by age.

TREATMENT

Clinicians should recognize that root canal therapy is far less traumatic than extraction for older patients.

The pulp vitality status and the cervical positioning of the rubber dam clamp determine the need for anesthesia. Older patients more readily accept treatment without anesthesia, and sometimes they must be convinced that anesthesia is necessary for root canal treatment if their routine operative procedures have been performed without it.

The cutting of dentin does not produce the same level of response in an older patient for the same reason that a test cavity is not as revealing during examination. The number of low threshold, high conduction velocity nerve endings in dentin is reduced or absent, and they do not extend as far into the dentin. In addition, the dentinal tubules are more calcified. A painful response may not be encountered until actual pulp exposure has occurred.

Clinical consideration for anesthetic technique:

1. Anatomic landmarks that are used as guides to needle placement during block and infiltration injections are usually more distinguishable in older patients.

2. The effects of epinephrine should be considered when selecting anesthetics for routine endodontic procedures.
3. The anesthetics should be deposited very slowly (and skeletal muscle avoided) if epinephrine is the vasoconstrictor.
4. The reduced width of the periodontal ligament makes needle placement for supplementary intraligamentary injections more difficult. Placing an anesthetic under pressure produces an intraosseous anesthesia that extends to the apex and to adjacent teeth, but it also distributes small amounts of solution systemically.
5. Similar amounts of anesthetic should be deposited during intraosseous injections, and the depth of anesthesia should be checked before repeating the procedure.
6. Like intrapulpal anesthesia, intraosseous anesthesia is not prolonged; therefore the pulp tissue must be removed within 20 minutes.
7. The reduced volume of the pulp chamber makes intrapulpal anesthesia difficult in single rooted teeth and almost impossible in multirooted teeth, initial pulp exposures are also hard to identify. Wedging a small needle into each canal to produce the necessary pressure for anesthesia is the method of last resort.

Every effort should be made to produce profound anesthesia. Patients should be encouraged to report any unpleasant sensation, and a prompt response should be made to any complaint. Patients should never be expected to tolerate pulpal pain.

Isolation

Single tooth rubber dam isolation should be used whenever possible. Badly broken down teeth may not provide an adequate purchase point for the rubber dam clamp, and alternate rubber dam isolation methods should be considered. Multiple-tooth isolation may be used if adjacent teeth can be clamped and saliva output is low or a well placed saliva ejector can be tolerated.

Canals should be identified and their access maintained if restorative procedures are indicated for isolation. The clinician should not attempt isolation and access in a tooth with questionable marginal integrity of its restorations. Fluid tight isolation cannot be compromised when sodium hypochlorite is used as an irrigant. Difficult-to-isolate defects produced by root decay present a good indication, in initial preparation, for the use of sonic hand pieces that use flow through water as an irrigant.

The many merits of single visit root canal procedures should again be considered when isolation is compromised. The few minor benefits of multiple visit treatment are further reduced if an interappointment seal is difficult to obtain.

Access

Adequate access and identification of canal orifices are probably the most difficult parts of providing root canal treatment for older patients. Although the effects of aging and multiple restorations may reduce the volume and coronal extent of the chamber or canal orifice, its buccolingual and mesiodistal positions remain the same and can be predicated from radiographs and clinical examination. Canal position, root curvature, and axial inclinations of roots and crowns should be considered during the examination .The effects of access on existing restorations should be discussed with the patient before proceeding. Coronal tooth structure or restorations should be sacrificed when they compromise access for preparation or filling.

Location and penetration of the canal orifice is often difficult and time consuming in calcified canal. The most important instrument for initial penetration is the DI 16 explorer. The explorer will not stick in solid dentin; however, it will resist dislodgment in the canal. Once the canal has been distinguished, negotiation is attempted with a stainless steel (SS) 21 mm, no 8 or no 10 K-file. The no. 6 file lacks stiffness in its shaft and easily bends and curls under gentle apical pressure. Nickel and titanium (NiTi) files lack strength in the long axis and are contraindicated for initial negotiation. The canal can be negotiated using a watch-winding action with slight apical pressure. Chelating agents are seldom of value

in locating the orifice but can be useful during canal negotiation. Dyes may distinguish an orifice from the surrounding dentin.

Pain, bleeding, disorientation of the probing instruments, or an unfamiliar feel to the canal may indicate a perforation .The size of the perforation and the extent of contamination determine the success of repair (which should be done immediately) and do not necessarily indicate failure .Supererupted teeth can be easily perforated if the reduced distance to the furcation is not noted.

A lengthy, unproductive search for canals is fatiguing and frustrating to both the clinician and the patient. Scheduling a second attempt is often productive. Personal clinical experiences and judgment determine when the search for the canals must be terminated and referral or alternatives to nonsurgical root canal treatment considered.

Convenience form

Modifications to enhance access vary from widening the axial walls to increasing visibility or light to complete removal of the crown. Alternations may be indicated after canal penetration to the apex if tooth structure interferes with instrumentation or filling procedures.

Very few canals of older teeth, even maxillary anterior teeth, have adequate diameter to allow the safe and effective uses of broaches. Older pulps may give a clinical appearance that reflects their calcified, atrophic state with the stiffened fibrous consistency of a wet toothpick. Any broached canals should be thoroughly instrumented at the same appointment.

The tooth length

The length of the canal from the actual anatomic foramen to the CDJ increases with the deposition of cementum throughout life. The advantage of this situation in the treatment of teeth with vital pulps is countered by the presence of necrotic, infected debris in this longer canal when periapical pathosis is already present.

The actual CDJ width or most apical extent of the dentin remains constant with age. Because this CDJ is the narrowest constriction of the canal, it is the ideal place to terminate the canal preparation. This point may vary from 0.5 to 2.5 mm from the radiographic apex and difficult to determine clinically. Calcified canals reduce the clinician's tactile sense in identifying the constriction clinically, and reduced periapical sensitivity in older patients reduces the patient's response that would indicate penetration of the foramen.Increasedincidenceofhypercementosis, in which the constriction is even farther from the apex, makes penetration into the cemental canal almost impossible. Achieving and maintaining apical patency is more difficult.

Apical root resorption associated with periapical pathosis further changes the shape, size and position of the constriction.

The use of electronic, apex-finding devices is sometimes limited in heavily restored teeth when contact with metal can bleed off the current.

Preparation

The calcified appearance of the canal resulting from the aging process presents a much different clinical situation than that of a younger pulp in which trauma, pulpotomy, decay, or restorative procedures have induced premature canal obliteration. Unless further complicated by reparative dentin formation, this calcification appears to be much more concentric and linear. This allows easier penetration of canals once they are found. An older tooth is more likely to have a history of earlier treatment, with a combination of calcifications present.

Flaring of the canal should be performed as early in the procedure as possible to provide for a reservoir of irrigation solution and to reduce the stress on metal instruments that occurs when they bind with the canal walls. Thorough and frequent irrigation should be performed to remove the debris that could block access. Files with a triangular or square cross section may penetrate into the walls with greater force than the fracture resistance of small files (when used with reaming action) and result in instrument fatigue and fracture. The benefits of instruments with no rake angle and a crown down technique should be considered.

The frequency and intensity of discomfort after instrumentation has not been shown to be related to the amount of preparation, the type of interappointment medication or temporary filling, the pulp or periapical status, the tooth number or age, or whether the root canal filling is completed at the same appointment. The more constricted dentin and cementum junction (DCJ) permits a much smaller pulp wound and resists penetration, even with the initial small files. Patency is difficult to establish and maintain. Dentin debris create a matrix early in the preparations and further reduces the risk of overinstrumentation or the forcing of debris into the periapical tissues.

Obturation

For the older patient the prudent clinician selects gutta percha-filling techniques that do not require unusually large midroot tapers and do not generate pressure in this area, which could result in root fracture.

The coronal seal plays an important role in maintaining the apically sealed environment, and it has significant impact on long-term success. Even a root filled tooth should not have its canals exposed to the oral environment. Permanent restorative procedures should be scheduled as soon as possible, and intermediate restorative materials should be selected and properly placed to maintain a seal until that time. When mechanical retention is not ensured with the preparation, glass ionomer cements are of value for this purpose.

Success and failure

Repair of periapical tissues after endodontic treatment in older patients with vital pulps, periapical tissues are normal and can be maintained with an aseptic technique, confining preparation and filling procedures to the canal space. Infected, nonvital pulps with periapical pathologic abnormalities must have this process altered in favor of the host tissue, and repair is determined by the ability of this tissue to respond. Factors that influence repair have their greatest effect on the prognosis of endodontic therapy when periapical abnormalities are present.

With aging, arteriosclerotic changes of blood vessels increase and the viscosity of connective tissue is altered, making repair more difficult. The rate of bone formation and normal resorption decreases with age, and the aging of bone results in greater porosity and decreased mineralization of the formed bone. A 6-month recall period to evaluate repair radiographically may not be adequate; it may take as long as 2 years to produce the healing that would occur at 6 months in an adolescent

Increased clinical indications for retrograde fillings when surgical treatment is attempted. As an isolated symptom, heat sensitivity may indicate a missed canal.

ENDODONTIC SURGERY

Generally, considerations and indications for endodontic surgery are not affected by age. The need for establishment of drainage and relief of pain are not common indications for surgery. Anatomic complications of the root canal system, such as small or completely calcified canals, nonnegotiable root curvatures, extensive apical root resorption, or pulp stones, occur with greater frequency in older patients.

Perforation during access, losing length during instrumentation, ledging, and instrument separation are iatrogenic treatment complications associated with treatment of calcified canals.

Medical considerations may require consultation but do not contraindicate surgical treatment when extraction is the alternative .In most instances surgical treatment may be performed less traumatically than an extraction, which may also result in the need for surgical access to complete root removal. A thorough medical history and evaluation should reveal the need for any special considerations, such as prophylactic antibiotic premedication, sedation, hospitalization, or more detailed evaluation.

Local considerations in treatment of older patients include an increase in the incidence of fenestrated or dehisced roots and exostoses. The thickness of overlying soft and bony tissue is usually reduced, and apically positioned muscle attachments extend the depth of the vestibule. Smaller amounts of anesthetic and

vasoconstrictors are needed for profound anesthesia. Tissue is less resilient, and resistance to reflection appears to be diminished. The oral cavity is usually more accessible with the teeth close together because the lips can more easily be stretched.

The apex can actually be more surgically accessible in older patients. Ability to gain such access varies with the skill of the surgeon; however, some areas are unreachable by even the most experienced clinicians.

The position of anatomic features, such as the sinus, floor of the nose, and neurovascular bundles, remains the same, but their relationship to surrounding structures may change when teeth have been lost. The need may arise to combine endodontic and periodontic flap procedures, and every effort should be made to complete these procedures in one sitting.

When apicoectomy is to be performed, the surgeon must consider whether the root that will be left is long enough and thick enough for the tooth to continue to remain functional and stable. This factor is especially important when the tooth will be used as an abutment.

RESTORATION

Root canal treatment saves roots, and restorative procedures save crowns. Combined these procedures are retaining more teeth to form and function than was thought possible just a few decades ago.

Special consideration must be given to post design, especially when small posts are used in abutment teeth; root fracture is common in older adults when much taper is used. Post failure or fracture occurs when small diameter parallel posts are used. Posts are not usually needed when root canal treatment is performed through an existing crown that will continue to be used.

The value of the tooth, its restorability, its periodontal health, and the patient's wishes should be part of the evaluation preceding endodontic therapy.

The restorability of older teeth can be affected when root decay has limited access to sound margins or reduced the integrity of remaining tooth structure. There can also be insufficient vertical and horizontal space when opposing or adjacent teeth are missing. Patient desires to save appliances can sometimes be fulfilled with creative attempts that may outlive them.

In conclusion, it can be seen that geriatric endodontics will gain a more significant role in complete dental care as our aging population recognizes that a complete dentition, and not complete dentures, is a part of their destiny.

CHAPTER REVIEW QUESTIONS

1. Demonstrate proper diagnosis and treatment plan for endodontic treatment of an elderly patient.
2. Compare the differences in endodontic steps treating an elderly and young patient.
3. Report any special considerations while performing endodontic surgery for an elderly patient.
4. Discuss any special considerations while restoring an endodontically treated tooth for an elderly patient.

REFERENCES

- Walton RE, Torabinejad M. Principles and practice of Endodontics, W.B. Saunders company, 4th edition 2009.
- Walton RE. Endodontic considerations in the geriatric patient. Dent Clin North Am. 1997 Oct;41(4):795-816.
- Allen PF, Whitworth JM. Endodontic considerations in the elderly. Gerodontology. 2004 Dec;21(4):185-94
- Nadig RR, Usha G, Kumar V, Rao R, Bugalia A. Geriatric restorative care - the need, the demand and the challenges. J Conserv Dent., 2011;14(3):208-214.
- Hargreaves KM, Cohen S, Berman LH. 10th ed. St.Louis: Mosby Year Book; 2011. Cohen's Pathways of the pulp.

32 The medically complex endodontic patient

TECHNICAL & CLINICAL ENDODONTICS

Alaa A. El-Baz

Intended Learning objectives

After reading this chapter, the student should be able to

1. Point out the importance of medical history and patient interview
2. Assess the need for treatment modifications
3. Determine the treatment modifications required for patients suffering from cardiovascular, renal and liver diseases, diabetes, pulmonary and blood disorders, central nervous system disorders, patients receiving radiation and chemotherapy, solid organ transplant or prosthetic devices and pregnant patients.
4. Describe any possible allergic reaction to materials used in endodontic therapy
5. Discuss the laboratory tests of potential importance in endodontics

Postgraduate students should be able to

- Appraise assessment, modifications in treatment plan and emergency management for medically compromised patients.

Chapter Outline

MEDICAL HISTORY AND PATIENT INTERVIEW
- ➢ MEDICATIONS AND ALLERGIES
- ➢ PREVIOUS DENTAL TREATMENT
- ➢ PHYSICAL EXAM: VITAL SIGNS
- ➢ RELATIVE STRESS OF THE PLANNED PROCEDURE AND BEHAVIORAL CONSIDERATIONS
- ➢ PHYSICAL HEALTH STATUS

- CARDIOVASCULAR DISEASE
  - ➢ HYPERTENSION
  - ➢ VASOCONSTRICTOR USE IN PATIENTS WITH CARDIOVASCULAR DISEASE
  - ➢ ISCHEMIC HEART DISEASE
  - ➢ HEART MURMURS AND VALVULAR DISEASE
  - ➢ ANTICOAGULANT THERAPY AND BLEEDING DISORDERS
  - ➢ ARRHYTHMIAS AND CARDIAC PACEMAKERS
  - ➢ CONGESTIVE HEART FAILURE
- DIABETES
- PULMONARY DISORDERS: ASTHMA, COPD, AND TUBERCULOSIS
- CENTRAL NERVOUS SYSTEM: STROKE, SEIZURE DISORDERS AND HYDROCEPHALIC SHUNTS
- RENAL DISEASE AND DIALYSIS
- CANCER CHEMOTHERAPY AND RADIATION THERAPY
- BONE MARROW AND SOLID ORGAN TRANSPLANTATION
  - ➢ HEMATOPOIETIC STEM CELL TRASPLANTATION
  - ➢ SOLID ORGAN TRANSPLANT
  - ➢ PROSTHETIC JOINTS TRANSPLANT
- PREGNANACY
- HUMAN IMMUNODEFICIENCY VIRUS
- LIVER DISEASE
- ADRENAL SUPPRESSION AND LONG TERM STEROID USE
- ALLERGY TO MATERIALS USED IN ENDODONTIC THERAPY
  - ➢ LOCAL ANESTHETICS
  - ➢ LATEX
  - ➢ ANTIBIOTICS AND ANALGESICS
  - ➢ IRRIGATING SOLUTIONS
  - ➢ INTRACANAL MEDICATIONS, CEMENTS AND FILLING MATERIALS
- LAB TESTS OF POTENTIAL IMPORTANCE IN ENDODONTICS

One of the challenges faced by dental specialists today is in the assessment and management of patients with increasingly complex medical conditions. Not only has the average life expectancy increased dramatically over the past 50 years. 25% of patients aged 65 to 74 and 35% of patients aged 75 and older have a medical condition. Endodontists should be prepared to accurately evaluate medically complex patients and identify situations that require a modification of normal treatment procedures and identify oral and systemic conditions .

Medically complex patients will be defined as any patient requiring modification of the usual treatment procedure.

MEDICAL HISTORY AND PATIENT INTERVIEW

"Never treat a stranger" (Attributed to sir William Osler).

25 to 30% of patients seeking treatment in a dental office can be expected to report at least one medical condition.

A standard health history questionnaire should cover all common medical conditions (both treated and untreated), surgeries, hospitalizations, medications, and allergies.

Written health history questionnaire should always be supplemented with a patient interview.

The reliability of self-reported information in the health history may be less than ideal.

MEDICATIONS AND ALLERGIES

The list of medications and allergies should be consistent with the disclosed medical conditions.

Herbs, dietary supplements, vitamins, and other over the counter medications can contribute to complications in the dental setting, although patients often fail to report the use of these substances in the initial evaluation.

Some nonprescription medications could potentially inhibit coagulation or interact with anesthetics and vitamin E may inhibit platelet aggregation and can increase the risk of bleeding.

Ingredients in over- the – counter (OTC) weight loss products can potentiate the effect of epinephrine and increase cardiac stress.

PREVIOUS DENTAL TREATMENT

Previous dental treatment serves several important functions. First, it allows the patient to discuss previous negative dental experiences as well as express possible anxiety related to proposed treatment.

A report of difficulty in achieving profound local anesthesia.

Potential adverse reactions to dental materials or drugs, it can serve as a good lead into other important but, potentially more sensitive questions.

PHYSICAL EXAM: VITAL SIGNS

Vital signs (blood pressure, heart rate, respiratory rate, temperature height, and weight) should be recorded prior to dental treatment. Blood pressure, heart rate, and respiratory rate provide baseline information.

Temperature recorded indicates the presence of infection or signs of generalized malaise or toxicity. Height and weight are important in determining appropriate drug dosages in pediatric and geriatric patients.

RELATIVE STRESS OF THE PLANNED PROCEDURE AND BEHAVIORAL CONSIDERATIONS

Clinical judgment is essential in determining whether or not stress-reducing treatment modifications should be employed.

Endodontic treatment in general is often considered a high- stress dental visit.

Surgical root canal procedures, the presence of acute pain, self- reported dental anxiety, or difficulty with previous treatment and lengthy procedures would all be expected to increase the level of stress. If any of these conditions are present in addition to significant systemic disease, treatment modification including a stress reduction protocol should be considered.

PHYSICAL HEALTH STATUS

(ASA) health classification system to determine the potential need for medical consultation and treatment modifications prior to dental and medical procedures.

ASA Classification	Description	Therapy modification McCarthy and Malamed,1979
ASA1	A normal healthy patient	None (stress reduction as indicated)
ASA2	A patient with mild systemic disease	Possible stress reduction and other modifications as needed
ASA3	A patient with a severe systemic disease that limits activity, but is not incapacitating	Possible strict modifications stress reduction and medical consultation are priorities
ASA4	A patient with an incapacitating systemic disease that is a constant threat to life	Minimal emergency care in office (may consist of pharmacologic management only); hospitalize for stressful elective treatment; medical consultation urged
ASA5	A moribund patient who is not expected to survive without the operation	Treatment in the hospital is limited to life support only; for example, airway and hemorrhage management
ASA6	A declared brain-dead patient whose organs are being removed for donor purposes	Not applicable

CARDIOVASCULAR DISEASE:

HYPERTENSION

Hypertension is one of the most common medical conditions.

Hypertensive patients are defined as those receiving treatment for hypertension or those with a mean systolic blood pressure(SBP) of 140 mg Hg or greater and/or a mean diastolic blood pressure (DBP) of 90 mg Hg or greater.

Patient with untreated or inadequately treated hypertension are at significantly increased risk for acute complications such as myocardial infarction (MI) and stroke and chronic complications of hypertension.

Classification	Systolic blood pressure (SBP) in mm Hg	Diastolic blood pressure (DBP) in mm Hg
Normal	<120	and<80
Prehypertension	120-139	Or 80-89
Stage I hypertension	140 159	Or 90 99
Stage 2 hypertension	≥160	Or ≤ 100

At least 15% of all adult dental patients have either untreated or inadequately treated hypertension, initial blood pressure measurement is an essential screening tool prior to dental treatment.

SBP below 160 and 180 or DBP between 90 and 100 should also be able to tolerate most dental procedures without significantly increased risk of perioperative cardiovascular complications; however, complexity and stress of the planned treatment should be carefully done with attention given to stress reduction strategies prior to treatment.

Patient with SBP geater than 180 and / or DBP greater than 110 should be referred for medical consultation and treatment prior to dental treatment and only emergency management of pain or acute infection should be considered. SBP above 210 and / or DBP above 120 should be referred for emergent medical evaluation.

VASOCONSTRICTOR USE IN PATIENTS WITH CARDIOVASCULAR DISEASE

Vasoconstrictors are used routinely in endodontic therapy as a component of local anesthetics and often as a hemostatic agent during periapical surgery.

Lidocaine with 1:100,000 epinephrine, is the usual anesthetic of choice for root canal therapy, although many nonsurgical procedures can be performed using local anesthetics without vasoconstrictor.

Epinephrine is preferred over norepinephrine or levanordefrin due to a decreased potential for alpha- receptor stimulation.

Patient with advanced cardiovascular disease, geriatric patients, and patients taking certain medications (e.g. MAO monoamine oxidase inhibitors and nonselective beta blockers) may have a reduced tolerance for vasoconstrictor containing local anesthetics.

Since local anesthetics with vasoconstrictors are very helpful in obtaining adequate hemostasis and visibility during periapical surgery, it may be difficult to perform the procedure using anesthetics without vasoconstrictors.

Adequate pain control is an essential component of endodontic therapy since pain related stress could stimulate the release of significant quantities of endogenous catecholamines. Different kinds of stress can increase the release of significant quantities of endogenous epinephrine by as much as 20 to 40 times over baseline value.

Most authors feel that 0.036 to 0.054 mg of epinephrine (approximately two to three cartridges of local anesthetic with 1:100,000 epinephrine) should be safe for all patients except those with severe cardiovascular disease.

Local anesthetics with vasoconstrictors should be avoided or used with extreme caution in patients with the following cardiovascular conditions: Severe or poorly controlled hypertension, arrhythmias, myocardial infarction (MI) within the past month, stroke within the past 3 months and uncontrolled congestive heart failure (CHF). An important exception to this general rule regarding vasoconstrictors in the choice of local anesthetic for intraosseous injections (IO).

A transient increase in heart rate can be expected in about two-thirds of patients receiving an IO injection using lidocaine with 1:100,000 epinephrine, although heart rate returns to near baseline within 4 minutes after injection.

ISCHEMIC HEART DISEASE

When coronary atherosclerotic heart disease becomes sufficiently advanced to produce symptoms, it is referred to as ischemic heart disease. Diminished blood perfusion of the myocardium due to coronary artery disease (artherosclerosis) is the underlying cause with hypertension as a common contributing factor to heart failure.

Chest pain secondary to ischemic heart disease results when the oxygen demand of the myocardium exceeds the oxygen supply. Transient pain is referred to as angina pectoris and is often described as an aching, squeezing sensation or tightness in the middle of the chest. Angina is often precipitated by physical activity or stress and may radiate to the arm or jaw and may present as facial or dental pain. Fear and anxiety associated with dental treatment may be a precipitation factor for angina.

Sublingual nitrates are the standard treatment for angina and should result in rapid reversal of symptoms. Patients should always be instructed to bring their usual antianginal medicine with them for dental appointments. If symptoms are not relieved with oral nitrates immediate emergency treatment should be initiated.

Patients with a history of recent MI or unstable angina should be able to tolerate routine dental procedures with local anesthesia, although medical consultation is required and conscious sedation with monitoring is often recommended.

Treatment modification consideration for patients with ischemic heart disease should include morning appointments, short appointments, oral premedication with an anxiolytic drug and / or nitrous oxide/ oxygen sedation, limited use of vasoconstrictors adequate pain management and possible cardiac monitoring.

HEART MURMURS AND VALVULAR DISEASE

Patients with valvular disease present two primary considerations for dental treatment: potential risk for infective endocarditis and risk of excessive bleeding in patient on anticoagulant therapy.

Most heart value abnormalities affect either the aortic or the mitral value and represent partial obstruction of blood flow (stenosis) or valvular incompetence (regurgitation).

Two other conditions that place patients at increased risk for infective endocarditis are systemic lupus erythematosus and certain medications used for weight reduction (dexfenfluramine and fenfluramine-phentermine).

Recently significant changes from previous American Heart Association guidelines are available.

Antibiotic prophylaxis is no longer recommended for patients with a history of mitral value prolapse (with or without regurgitation) rheumatic heart disease, bicuspid valve disease, aortic stenosis, and certain congenital heart conditions.

Antibiotic prophylaxis is now recommended only for patient with valvular disease associated with the highest risk of adverse outcomes from infective endocarditis

For patients in the highest risk category, antibiotic prophylaxis is recommended for dental procedures that involve manipulation of gingival tissues or the periapical region of teeth or perforation of the oral mucosa.

Antibiotic prophylaxis recommended
Highest risk of adverse outcome infective endocarditis:
Prosthetic heart value
Previous infective endocarditis
Congenital heart disease(CHD)
Unrepaired cyanotic CHD, including palliative shunts and conduits
Completely repaired congenital heart defect with prosthetic material or device, whether placed by surgery or catheter, during the first six months after the procedure
Repaired CHD with residual defects at the site or adjacent to the site of a prosthetic patch or prosthetic device
Cardiac transplantation recipients who develop cardiac valvulopathy

Antibiotic prophylaxis recommended *only for patients at highest risk for adverse*

outcome from infective endocarditis

All dental procedures that involve manipulation of gingival tissue or the periapical region of teeth or perforation of the oral mucosa (dose not include routine local anesthetic injections through noninfected tissue)

Standard oral regimen	Adults:2.0g Amoxicillin Children: 50mg/kg
Alternative oral regimen for patients allergic to penicillin or patients who are currently taking a penicillin class antibiotic	Adults: 2.0 Cephalexin or other 1^{st} or 2^{nd} generation cephalosporin in equivalent dosage OR 600mg clindamycin OR 500mg azithromycin or clarithromycin Children: 50mg/kg Cephalexin or other 1^{st} or 2^{nd} generation cephalosporin in equivalent dosage OR 50mg/kg IM or IV Cefazolin or Ceftriaxone
Alternative IM/IV regimen for patients allergic to penicillin and unable to take oral medications	Adults: 1.0g IM or IV Cefazolin or Ceftriaxone OR 600mg IM OR IV clindamycin Children: 50mg/kg IM or IV Cefazolin or Ceftriaxone OR 20mg/kg IM or IV clindamycin within 30 minutes before the procedure

Procedures associated with nonsurgical root canal treatment such as local anesthetic injection placement of the rubber dam, and instrumentation when contained within the canal system do not place the patient at significant risk for infective endocarditis. The incidence and magnitude of bacteremia when canal instrumentation does not extend into the periapical tissues is very low and almost all bacteria are eliminated from the blood within 10 minutes.

Canal instrumentation beyond the apex, intraligamentary and IO injections, and periapical surgery can all be expected to result in a higher risk for transient bacteremia. In these situations, antibiotic premedication is recommended for patients in the highest risk disease categories.

Some patients with significant heart murmurs may have dyspnea, fatigue and difficulty in breathing when reclined in the dental chair and therefore the dental procedure may need to

be performed with the chair in a more upright position. They also suggest that the use of a rubber dam may be contraindicated for some of these patients due to restriction of air flow; however, this may be overcome with careful application of the rubber dam. Failure to use the rubber dam is considered below the standard of care for root canal therapy and extraction may be the only option for these patients if a rubber dam cannot be used.

ANTICOAGULANT THERAPY AND BLEEDING DISORDERS

Anticoagulant works by blocking the formation of prothrombin and other clotting factors. The international normalized ratio (INR) value is the accepted standard for measuring prothrombin time (PT). the desired therapeutic range for INR is usually between 2 and 3.5

Nonsurgical root canal treatment does not usually require modification of anticoagulant therapy, although it is important to ascertain that the patient's INR is within the therapeutic range, especially if a nerve block injection is required. In cases of periapical surgery consultation with the patient's physician is required.

Low-dose aspirin therapy increase bleeding time by irreversibly inhibiting platelet aggregation. No treatment modifications should be necessary for nonsurgical root canal procedures.

In surgical procedures advise patients to discontinue aspirin therapy for 7 to 10 days prior to an oral surgical procedure and bleeding could be controlled by local measures.

Some (NSAIDs) also have an antiplatelet effect but, unlike aspirin the effect is reversible so when discontinued the platelet activity should be expected to return to normal within approximately three half-lives of the drug.

Heavy alcohol consumption, liver disease, and certain medications can increase the risk of preoperative bleeding in patients taking antiplatelet medication. Medical consultation is advised prior to surgical procedures.

Some herbs and dietary supplements may also affect bleeding risk.

Medical consultation is required prior to dental treatment for patients with serious bleeding disorders such as thrombocytopenia, hemophilia, and Von Willebrand's disease. Replacement of deficient coagulation factors or platelet transfusion may be required prior to dental treatment.

ARRHYTHMIAS AND CARDIAC PACEMAKERS

Cardiac arrhythmias are disturbance in the normal rate or rhythm of the heartbeat. Anxiety associated with dental treatment may induce arrhythmias in susceptible patients.

Patients with cardiovascular disease are more prone to arrhythmias during oral surgery procedures with local anesthesia.

Dental treatment can be safely performed using the same stress reduction treatment modifications. Recent clinical studies concluded that EAL and EPT devices should be safe to use in patients with cardiac pacemakers and cardioverter / defibrillators.

Now mucosal lip clip is used to complete the circuit with the EPT device instead of having the patient hold the EPT wand in their hand.

Using the patients hand to complete the circuit may allow for electrical current to pass through an area of the body in closer proximity to the pacemaker.

CONGESTIVE HEART FAILURE

Well- manged CHF should tolerate routine dental treatment with possible minor treatment modifications. Patients with moderate to advanced CHF may require a more upright chair position due to the presence of pulmonary edema.

Uncompensated, advanced CHF requires medical consultation prior to dental treatment and vasoconstrictors should be avoided.

New York Heart Association CHF Classification	Signs and symptoms	Dental management Considerations
Class 1	No limitations no physical activity; no dyspnea, fatigue, or palpitations with ordinary physical activity	Should be able to tolerate routine dental treatment; stress reduction protocol as needed
Class 2	Slight limitation on physical activity; comfortable at rest but may experience fatigue, palpitations, and dyspnea with ordinary physical activity	Should be able to tolerate routine dental treatment; stress reduction protocol as needed; possible medical consultation
Class 3	Significant limitation of activity; comfortable at rest but even minor activity result in symptoms	Medical consultation consider treatment in hospital dental clinic or similar facility; avoid vasoconstrictors
Class 4	Symptoms present at rest; symptoms exacerbated by any physical activity	Medical consultation conservative treatment only; treatment in hospital dental clinic; avoid vasoconstrictors

DIABETES

DM is defined as a fasting blood glucose level greater than 125 mg/dl and the normal fasting blood glucose level is considered to be less than 110 mg/dl.

Avoidance of appointments that will overlap with or prevent scheduled meals. Symptoms of hypoglycemia may range form mild such a anxiety, sweating, tachycardia, to severe, such as mental status changes, seizure, and coma. Severe hypoglycemic episodes are a medical emergency and should promptly be treated with 15g of oral carbohydrate, such as 6 oz orange juice, three to four teaspoons of table sugar.

If a patient is unable to cooperate or swallow, 1 mg glucagon may be administered by subcutaneous or intramuscular injection.

Surgical procedures in well-controlled diabetics do not require prophylactic antibiotics. When surgery is necessary in the poorly controlled diabetic, prophylactic antibiotics should be considered due to the altered function of neutrophils in diabetics.

Delayed alveolar healing raise the suspicion of osteomyelitis, for which prompt surgical consultation should be arranged.

PULMONARY DISORDERS: ASTHMA COPD AND TUBERCULOSIS

Asthma is a chronic inflammatory respiratory disease with recurrent episodes of chest tightness, coughing, dyspnea, and wheezing.

Patients should be instructed to bring their inhalers (bronchodilators) to each appointment.

During dental treatment, the most likely times for an acute exacerbation of asthma are during and immediately after local anesthetic administration because stress is implicated as a precipitating factor in asthma attacks. Sedation may be beneficial while nitrous oxide may be

used in patients with mild- to- moderate asthma due to its potential to cause airway irritation. Alternatively, oral premedication may be accomplished with small doses of a short- acting benzodiazepine.

Patients with pulmonary disease, in a semisupine position the use of a rubber dam may induce a feeling of airway constriction, careful application of the rubber dam and administration of humidified low- flow oxygen. may be considered.

(TB) is an infectious disease that is spread by bacilli-containing airborne droplets typically by coughing sneezing or talking

Oral tubercular infections are rare, occurring in 0.05 to 5% of patients with TB, though when lesions are present, they typically consist of ulcers, fissures, or swelling on the dorsum of the tongue. In patients with suspected active TB, dental treatment should be delayed until the individual can be treated and subsequently proved noninfectious. Routine dental treatment is appropriate after it has been established. The clinician should be aware of potential drug interactions when managing dental patients undergoing antitubercular treatment.

CENTRAL NERVOUS SYSTEM: STROKE, SEIZURE DISORDERS AND HYDROCEPHALIC SHUNTS

Blood pressure should be checked before treatment to identify a patient whose blood pressure is elevated and who might be at risk for a stroke if subjected to stress. Slurred speech loss of motor control over a portion of the body, unilateral facial droop, unilateral visual changes, and unilateral severe headache are all potential signs of a stroke. If any of these events occur, the patient should have his/her vital signs checked, be placed in a supine position, have vital signs monitored, and be transported to an emergency facility. Patients with a history of stroke may be at risk for aspiration due to swallowing abnormalitis, so they should be positioned in a semisupine position, and rubber dams should be always used. Most people who have seizers have good control and are capable of receiving routine dental care. The endodontist should be aware of the patient's seizure medications, since many antibiotics are contraindicated. Should a seizure occur in the dental office, the procedure should be stopped immediately and all instruments should be removed from the oral cavity. The patient should be placed in a supine position and low to the ground. Basic life support should begin immediately, including opening the airway, obtaining vital signs such as heart rate and blood pressure, and contacting emergency medical services. The risk of shunt infection following invasive dental treatment for patients with hydrocephalic recommends penicillin prophylaxis

RENAL DISEASE AND DIALYSIS

Chronic renal failure is a slowly progressive condition characterized by an irreversible reduction in the glomerular filtration rate. The progression of this disease begins with an asymptomatic decrease in the kidney function and eventually results in end- stage renal disease(ESRD).

ESRD is potentially fatal unless the patient undergoes dialysis or kidney transplantation. Dialysis removes fluid and wastes and equilibrates electrolytes and acid-bases via diffusion and osmosis across a semipermeable membrane.

Mechanical trauma to platelets and anticoagulants such as heparin used during hemodialysis may increase the renal patient's tendency for bleeding. It is recommended that dental procedures be performed on nondialysis days, typically the day after dialysis, the endodontist should be aware that abnormal platelet function may cause a greater risk of bleeding during surgical procedures.

Infections antibiotic premedication have also been recommended for hemodialysis patients to prevent vascular access infections, bacteremia and infective endocarditis. Renal osteodystrophy and secondary hyperparathyroidism may occur in late stage disease due to disorders in calcium phosphorous and abnormal vitamin D metabolism such a manifestation may predispose renal patients to jaw fracture during surgical procedures.

Because many drugs are metabolized via the kidney, renal dosing should account for the drug's extended half-life by lengthening the interval between medication doses. In particular, antibiotic medications should be adjusted for renal dosing. NSAIDs should be avoided in patients with renal insufficiency due to their nephrotoxic effects, but on longer need to be avoided when the patient has ESRD.

CANCER CHEMOTHERAPY AND RADIATION THERAPY

Prior to cancer treatment, all sources of inflammation and potential infection should be eliminated.

Many cancer patients have indwelling catheters that may be susceptible to infection and while controversial, the American Heart Association (AHA) regimen for antibiotic prophylaxis has been recommended before invasive dental procedures. If an individual is receiving chemotherapy, the endodontist should be familiar with the patient's white blood count (WBC) and platelet status. Endodontic procedures can be performed if the neutrophil count is greater than 2000 cells per cubic millimeter and platelets are greater than 50,000 cells per cubic millimeter. Postradiation osteonecrosis (PRON) induced changes in the jaws impose, protocols to reduce the risk of osteonecrosis include selection of endodontic therapy over extraction, use of nonlidocaine local anesthetics that contain no or low concentration of epinephrine, and prophylactic antibiotics plus antibiotics during the week of healing.

BONE MARROW AND SOLID ORGAN TRANSPLANTATION

HEMATOPOIETIC STEM CELL

TRASPLANTATION

Prior to transplantation patients should undergo a thorough dental examination and treatment to permit adequate healing before the HSCT. Pretreatment endodontic therapy should be completed at least 10 days prior to initiation of cancer therapy. Teeth with poor prognoses should be extracted.

Instituted numerous oral complications may develop including mucositis, graft-versus- host disease, infection, taste change, and bleeding. Patients should not resume routine dental treatment, including dental scaling and polishing, until adequate immunological reconstitution has taken place. This typically occurs in less than 1 year posttransplant. The aerosolization of debris and bacteria during the use of high speed rotary cutting instruments can put the patient at risk for aspiration pneumonia. Additionally, bacteremias occur as a result of dental treatment and can cause serious outcomes.

SOLID ORGAN TRANSPLANT

Pertransplant patients should undergo eradication of dental disease, including endodontic procedures as warranted to remove any potential sources of infection, and deferral of any elective treatment.

Immediate posttransplant period emergency dental procedures may be necessary at this stage. Patients are highly immunosupperssed to prevent organ rejection, so the AHA regimen of antibiotic prophylaxis with possible postoperative antibiotics may be recommended for invasive procedures.

After the posttransplantation and the patient has been stabilized indicated dental procedures may be performed after consultation with the patient's transplant team.

Finally the endodontist should be aware that posttransplant recipients will likely be on immunosuppressant therapy regardless of the length of time posttransplantation .

PROSTHETIC JOINTS TRANSPLANT

Increased risk for developing a hematogenous joint infection following dental procedures so there is a necessity for prophylactic antibiotics

Patient type	Suggested Drug	Regimen
Patients not allergic to penicillin	Cephalexin, cephradine or amoxicillin	2 grams orally 1 hour prior to dental procedure
Patients not allergic to penicillin and unable to take oral medications	Cefazolin or ampicillin	Cefazolin 1g or ampicillin 2g intramuscularly or intravenously 1 hour prior to the dental procedure
Patient sllergic to penicillin	Clindamycin	Clindamycin 600 mg orally 1 hour prior to the dental procedure
Patients allergic to penicillin and unable to take oral medications	Clindamycin	600mg intravenously 1 hour prior to the dental procedure

The selection of antibiotic and dosage regimen differs slightly from the commonly accepted regimen for prevention of bacterial endocarditis. Antibiotic prophylaxis is not indicated for dental patients with pins, plates, screws, and penile or breast implants; nor is it routinely indicated for dental patients 2 years after total joint replacements.

PREGNANACY

There is no contraindication to using necessary diagnostic procedures, such as appropriate radiographs, as long as normal safety precautions are followed. Endodontic therapy should be provided regardless of the patient's phase of pregnancy. Elective dental procedures may often be performed in the second trimester.

Some medications may be harmful to the fetus, safe alternatives are often available.

A common misconception is a concern over the use of local anesthetics containing epinephrine. Local anesthetics containing epinephrine should be relatively safe for use during pregnancy and allow for greater depth and duration of anesthesia as well as reduction of any potential systemic effect of lidocaine. In addition, the only commonly available alternative to local anesthetics with a vasoconstrictor is 3% mepivicaine.

Pregnant women may be more susceptible to infection which may be partly due to physiological changes as well as alternations in pharmacokinetics.

HUMAN IMMUNODEFICIENCY VIRUS

The most effective management in the progression of HIV infection and AIDS is a combination of antiviral agents known as highly active antiretroviral therapies (HAART).

No modification of irreversible procedures of surgical treatment is recommended unless patients have reduced platelet count (<50,000 cells per milliliter) or neutrophil counts <1,000 cells per milliliter.

Routine antibiotic use is contraindicated. The prognosis for successful healing of necrotic teeth with chronic apical periodontitis following root canal treatment is essentially the same for HIV positive patients as for noninfected patients. Antibiotics are used only if warranted by the clinical infection, and in a neutropenic patient.

LIVER DISEASE

Performing any surgery in the preliver transplant patient involves the risk of severe hemorrhage due to thrombocytopenia or reduced hepatic synthesis of coagulation factors. Preoperative evaluation should include a complete blood and platelet count, PT or INR, and partial thromboplastin time to ensure an intact coagulation system. Patients with cirrhosis have an increased susceptibility to infection.

Antibiotic prophylaxis prior to dental procedures is recommended.

A recommended oral regimen is 2.0 g of amoxicillin plus 500mg of metronidazole 1 hour before the dental procedure, or patients may be given 2.0g of ampicillin plus 500mg of metronidazole intravenously 1 hour before the procedures.

Alteration of medication dosage based upon hepatic compromise, additional medications, and site of metabolism of the medication may require consultation with the patient's physician.

ADRENAL SUPPRESSION AND LONG TERM STERIOD USE

Supplemental steroids are often recommended before and possibly following surgery to prevent adrenal crisis in patients who receive chronic daily steroid therapy. For minor surgical procedures such as routine endodontic surgeries, the glucocorticoid target is about 25mg of hydrocortisone equivalent (5mg of prednisone) on the day of surgery. If a moderate risk surgery is to be performed the glucocorticod target is about 50 to 75 mg per day of hydrocortisone equivalent on the day of surgery and for one postoperative day. Nonsurgical dental procedures, including nonsurgical root canal treatment generally require no supplementation; however, this should be reviewed on a case by case basis and consideration.

As a rule of thumb, a patient who recently discontinued the use of exogenous corticosteroids should wait 2 weeks before undergoing surgical procedures. Patients on alternate day steroids do not likely require steroid supplementation. Efforts to control pain and infection can decrease the risk of an adrenal crisis.

ALLERGY TO MATERIALS USED IN ENDODONTIC THERAPY

Approximately 15 to 20% of dental patients report some form of allergy on their medical history questionnaire and approximately 5% report allergy to one or more drugs.

The medical history questionnaire serves as the first stage in screening for allergies but should always be supplemented with direct patient questioning about the history of allergic reactions to any drugs or substances. True allergic reactions are characterized by one or more of the following signs and symptoms; skin rash, swelling urticaria, chest tightness, shortness of breath, rhinorrhea, and conjunctivitis. Type I (immediate or anaphylactic IgE-mediated) and type IV (delayed, cell-mediated) are the two types of allergic reactions most likely to be encountered as a result of exposure to a substance used in endodontic treatment. Type I hypersensitivity requires previous exposure to the antigen and can occur after a single prior exposure of multiple prior exposures to the allergen. The reaction occurs shortly after exposure and can rapidly progress to life- threatening anaphylaxis. Type IV hypersensitivity typically appears 48 to 72 hours after exposure and is mediated by T lymphocytes in contrast to the humoral immune system (antibody)-mediated type I reaction. Contact dermatitis is a classic Type IV reaction.

LOCAL ANESTHETICS

Sulfite preservatives used in local anesthetics containing epinephrine and latex allergen released into the anesthetic solution from the vial stopper are potential causes of allergic reactions. Although reaction to the sulfite preservative is also believed to be rare, since preservatives are used only in local anesthetics containing a vasoconstrictor, the risk of allergic reaction

from this potential source can be eliminated by using an anesthetic without vasoconstrictor and preservative (e.g. 3% mepivicaine). Local anesthetic cartridges contain two potential sources of latex allergen that could possibly leach into the anesthetic solution- the rubber stopper and the diaphragm.

As a practical matter, patients referred for allergy testing should be given sample cartridges of at least two different local anesthetics so that the allergist can test with the same solution that will be used for dental treatment.

A solution of 1% diphenhydramine with 1:100.000 epinephine can be compounded by a local pharmacist and used for infiltration or mandibular block injections. The dosage should be limited to a maximum of 50 mg at each appointment.

LATEX

Of the many materials used in the dental office with the potential for initiating an allergic reaction natural rubber latex (NRL) is the most common. Type IV sensitivity is the most common type and is related to the various chemicals used in processing of NRL. The potentially much more serious Type I sensitivity to NRL is a reaction to proteins found in NRL. Urticaria is the most common intial finding in Type I sensitivity reaction to NRL. Patients with a history of multiple surgeries and health care workers all have an increased risk of sensitivity to NRL. Some food allergies (e.g. avocado and banana) are associated with an increased risk of latex allergy considering the multiple potential sources of exposure to NRL in the dental office (e.g. rubber dam material, gloves, local anesthetic cartridges, rubber mouth props, rubber tubing and even some blood pressure cuffs). History of allergy to NRL requires special treatment modification, in addition, clinicians who treat patients with known or suspected sensitivity to NRL should be prepared to provide initial management of an acute allergic reaction if necessary.

Consultation with the patient's primary care physician or allergist is advised to help assess the degree of risk, previous reactions and treatment, and possible premedication with a corticosteroid. All potential sources of NRL exposure in the dental office should be considered. Non latex gloves and rubber dam materials are now readily available from commercial sources and these items may be easily substituted for NRL-containing products since latex allergens can be transferred by contact with powder from latex gloves and other sources. It may be prudent to schedule the patient as the first of the day to decrease the chance of contact with residual latex allergens on environmental surfaces, clothing, and room air.

ANTIBIOTICS AND ANALGESICS

Allergy to penicillin is one of the most common drug allergies and affects approximately 2.5 million people .

It should be presumed that the patient is also allergic to the synthetic penicillin. In addition, cephalosporins show cross-reactivity in approximately 5% to 10% of penicillin allergic patients. Clindamycin is an appropriate alternative to penicillin for treatment of endodontic infections and bacterial endocarditis prophylaxis.

Clarithromycin is another medication that can be considered.

NSAIDs are the usual druges of first choice for management of endodontic- related pain and are tolerated well by most patients. However, caution should be used in prescribing NSAIDs in patients with asthma and / or known allergy or sensitivity to aspirin.

IRRIGATING SOLUTIONS

Allergic reaction and/or hypersensitivity to sodium hypochlorite when used as an endodontic irrigating solution is rare. Alternative to sodium hypochlorite include sterile saline

or water, chlorhexidine hydrogen peroxide (3%), ethylenediamine tetraacetic acid (EDTA, 10% to 17%), citric acid (10%), and a recently introduced material, MTAD.

Of these alternatives, iodine potassium iodide and chlorhexidine possess the potential for stimulating an allergic reaction.

INTRACANAL MEDICATIONS, CEMENTS AND FILLING MATERIALS

Intracanal medications such as formocresol formaldehyde, eugenol, camphorated phenols and cresatin are all known to be potential allergens.

Calcium hydroxide paste, a commonly used intra-appointment medication, is not allergenic. Temporary filling materials containing zinc oxide and eugenol (ZnOE) have the potential for allergic reactions and, unlike materials contained exclusively within the confines of the root canal space, are likely to have contact with mucosal tissues.

Zinc oxide and eugenol, a potential allergen, is a common component of many root canal sealers and two common root-end filling materials (IRM and super EBA). Sealers containing formaldehyde or paraformaldehyde (such as N2 paste and Endomethazone), especially when extruded beyond the apex, have been demonstrated to stimulate often severe allergic reactions. Resin-based sealers such as AH26 and AHPlus also have the potential to stimulate an allergic response although this is believed to be rare. Calcium hydroxide based sealers such as Sealapex or glass ionomer sealers such as Ketac-Endo could be reasonable alternatives for patients with known allergy to any of the components of ZnOE or resin-based sealers.

Dentin-bonded resin-type root-end filling materials have demonstrated no evidence of allergic reactions. MTA has demonstrated excellent biocompatibility and no suspected allergic potential.

Suspected allergic reactions to gutta-percha in patients who were allergic NRL.

Gutta percha contains other ingredients such as barium sulfate, zinc oxide, waxes, and coloring agents; so potential allergy to any of these materials should be considered, especially if there is a potential for extrusion of filling material. Newer non-gutta- percha filling materials (e.g. resilon) show promise but could be expected to contain many of the same added ingredients as commercially available gutta-percha. In patients with multiple allergies (atopy) and suspected allergy to any of the components of gutta-percha consultation with the patient's physician is advised. If safe use of the standard oburating material cannot be confirmed, one alternative is to fill the root canal space with MTA.

LAB TESTS OF POTENTIAL IMPORTANCE IN ENDODONTICS

Dentists may be uncomfortable in ordering laboratory tests. Referral to a physician is always appropriate, but there is no reason for a dentist to be intimidated by the process. Dentists are often the first healthcare provider to identify systemic disease. Frequently, this is the case because oral tissues are the first to be affected. Also, many patients do not regularly visit their physician, or many receive only cursory information on subtleties of oral changes from disease. Leukemia, on subtleties endocarditis-induced oral petechiae, bleeding disorders various cancers, and many other diseases are first suspected in the dental office. Ordering a laboratory test to confirm or rule-out suspicions is perfectly appropriate for any dentist. Culture and sensitivity testing for identification of the cause of an infection and the most likely effective antimicrobial should be in every dentist's armamentarium.

Laboratory tests are commonly helpful to dentists. Disorders of inflammation, perhaps related to a chronic dental infection, may cause an increased erythrocyte sedimentation rate.

Blood tests can be helpful in identifying blood dyscrasias from cellular imbalances to inflammatory system evaluation and to clotting factors. Most classic hemophiliacs are diagnosed early in life and can provide the dentist with important information by history. Every dentist should be aware of the risks associated with altered blood clotting profiles of their patients. Newly identified risk assessment studies have shown the mortality and morbidity of decreasing anti-clotting parameters. The dentist should be comfortable in interpreting these tests to determine if a patient is a candidate for a surgical procedure.

A patient is a candidate for a surgical procedure the prothrombin time test has been largely replaced by the INR, which uses a standardized control and expresses the result in a percent of normal clotting time. This test evaluates the extrinsic clotting mechanism. With an INR of 1 being the normal level, minor dental-alveolar surgery can be carried out to a INR level < 3.5 with local methods of hemostasis sufficing for other than minor surgery, consultation should be obtained with consideration for modification of the anticoagulation or hospitalization.

The partial thromboplastin time test remains valuable to determine the intrinsic clotting pathway, which is the clotting factors in blood plasma. Bleeding time, the number of minutes required for a standard wound to clot, may help diagnose later onset problems of importance to the dentist such as von Willebrand's disease, where the intrinsic factor VIII is diminished by this hereditary defect. Also, bleeding time identifies disorders of the platelet system, including those induced by salicylates or NSAIDs.

Complete blood counts enumerate platelets, different white blood cells, and red blood cells and can confirm or rule out many suspicious findings. An increased numbers of red cells, polycythemia vera, can reveal itself as darker gingiva, because of the engorgement of the vascular system. Bleeding gingiva can be seen in many forms of leukemia. Petechiae due to sickle cell anemia can be diagnosed by the occasional characteristic shaped red blood cells.

While it is easier to direct patients and staff who are accidentally exposed to blood-born pathogens to someone trained in counseling for such risks, tests for such infectious agents may be ordered by the dentist who expects a disease.

Patients with unexplained radiolucencies of their jaws may need testing for certain disorders. For example, a multiple myeloma patient will have the abnormal Bence Jones protein in their urine. A patient with hyperparathyroidism-caused bone radiolucencies will have elevated blood calcium and decreased blood phosphorus. Urine phosphorus serum alkaline phosphatase is elevated in hyperparathyroidism, although not as markedly as with paget's disease.

Diabetes mellitus has broad implication in healing blood or urine glucose elevations can be the impetus needed to send a patient for medical care.

Allergies can make life unpleasant for many. They may stem form food allergies which can cause nutritional imbalances which may be suggested by changes in oral tissues. They may include dental materials, such as nickel or eugenol, making the patient less likely to have a favorable treatment outcome. The dentists who suspect such a problem will probably refer the patient to an allergist for skin or other tests and then help manage the dental aspects of the patient's care.

Chapter Review Questions

- Point out the importance of medical history and patient interview and the need for treatment modifications.
- Assess how the complex medical history could modify the treatment plan.
- Identify possible treatment modifications for pregnant patients.
- Describe any possible allergic reaction to materials used in endodontic therapy.
- Discuss the laboratory tests of potential importance in endodontics.

References

- Goodchild J, Glick M. Adifferent approach to medical risk assessment. Endod Top 2003;4:1-3.
- MorrisAM, WebbGD. Antibiotics before dental procedures for endocardiatis prophylaxis: back to the future. Heart 2001;86(1):3-4.
- Walton RE, Torabinejad M. Principles and practice of Endodontics, W.B. Saunders company, 4th edition 2009.
- Cohen S, Burns R C. Pathways of the pulp, Mosby, 10th edition 2011.
- Ingle J, Bakland LK, Baumgarner JC. Ingle's endodontics, BC Decker Inc, 6th edition 2008.

33

Nanotechnology in Endodontics

Hend Abou El Nasr
Marwa Bedier

Intended Learning objectives

After reading this chapter, the student should be able to

1. Define nanotechnology
2. Recognize the different types of nanotechnology and nanoparticles
3. Describe methods of synthesis of Nanoparticles.
4. Assess the medical and dental applications of nanomaterials.
5. Name the uses of nanotechnology in the field of dentistry
6. Relate the properties of the nanoparticles to the possible applications in endodontics
7. Outline the application of nanotechnology in endodontics.
8. Correlate the importance of nanomaterials and drug delivery systems.
9. Evaluate the importance of nanomaterials in microbial eradication.

Chapter Outline

• INTRODUCTION

BIOMATERIAL:

- A biomaterial is any matter, surface, or construct that interacts with biological systems. As a science, biomaterial is about fifty years old.
- The study of biomaterials is called biomaterials science.
- Biological biomaterials are discussed in terms of tissue engineering and stem cell research and nanotechnologies.

Nanotechnology:

The term nano is adapted from a Greek word means; Dwarf. (meaning extremely small).These small scientific scales were first revolutionized by Richard Feynman at his famous speech at the Annual Meeting of the American Physical Society in 1959 [1,2]

NANOMETER (nm): is one billion (10^{-9}) of a meter, or roughly the length of three atoms side by side [3]

DNA double-helix has a diameter around is 2.5 nm wide, a human hair is approximately 10,000nm thick.

NANOSCIENCE: is the study of phenomena and mainpulation of materials at the nanoscale (1-100 nanometers)

NANOTECHNOLOGY: also known as molecular nanotechnology or molecular engineering and sometimes shortened to "nanotech". It is the manipulation of matter on an atomic and molecular scale. It is the production of functional materials and structures in the range of 1-100 nm[4-5]. It involves the tailoring of materials at atomic level to attain unique properties, which can be suitably manipulated for the desired application[7].

•Nanomaterials (Fi g . 1)

Nanomaterials are categorized according to their dimensions as [3]:

1. All three dimensions less than 100nm, e.g., Nanoparticles.
2. Two dimensions less than 100nm, e.g., Nanotubes.
3. One dimension less than 100nm, e.g., thin films.

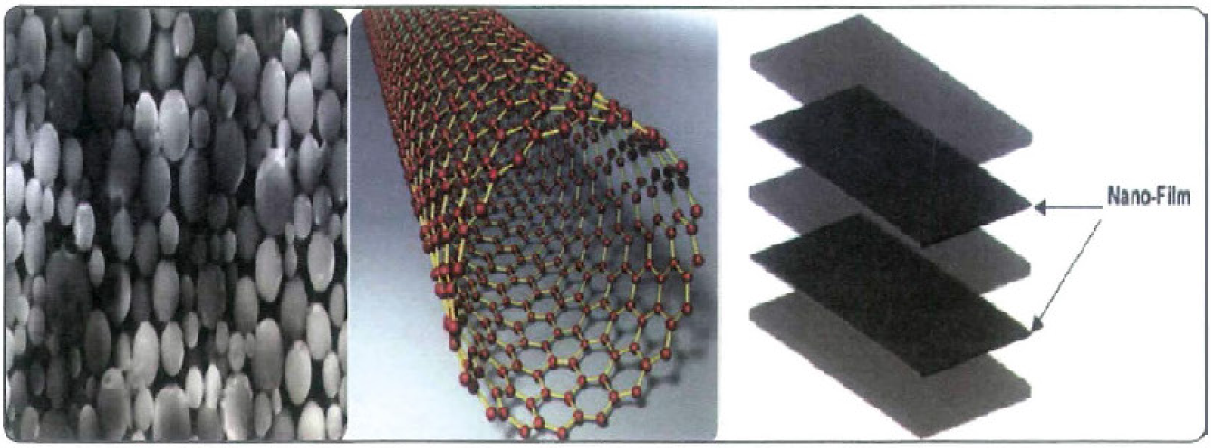


Fig. 1. Different dimensions of nanomaterials

•Properties of nanoparticles:

What makes " nano " special ??

A- **Quantum effect:** at the NANOMETER SCALE, the properties of matter, like electrical conductivity, color, strength or weight change. This is consequence of the small size of the nanomaterials, physicaly explained as Quantum effect. Ex: Bulk of silver is nanotoxic, whereas nanosilver has antibacterial properties.

B- **Surface to volume ratio** (Fig.2): Nanomaterials have an increased surface to volume ratio compared to bulk materials; this means that for a given volume of a material, the external surface is greater if it's made of nanomaterials sub-units than of bulk material.

Fig. 2. 1kg of particles of 1 mm^3 has the same surface area as 1 mg of particles of 1 nm^3.

C- Nanoparticles possess an **extremely large surface free energy**, which affect its chemical reactivity and increased production of reactive oxygen species (ROS) that have potent antimicrobial effect. Also, cause the nanoparticles to agglomerate to form either clusters or larger particles to minimize the total surface or interfacial energy of the system[9]. Which occur at the synthesis stage, during drying and subsequent processing of the particles. Thus, it is very important to stabilize the particles against agglomeration at each step of particle production and powder processing.

• Types of nanoparticles (NPs):

Nanoparticles can be organic polymers (organic NPs) and/or inorganic elements (inorganic NPs) [10].

Liposomes, dendrimers, carbon nanomate rials are examples of organic NPs. While inorganic NPs, such as polystyrene, magnetic, ceramic, and metallic NPs, have a central core composed of inorganic material that define their fluorescent, magnetic, electronic and optical properties[11].

Materials referred to as "nanomaterials" generally fall into two categories [12,13,8]:

1) **Fullerenes:** are any molecules composed entirely of carbon, in form of hollow sphere, ellipsoid, tube, and many other shapes. Spherical fullerenes are called buckyballs, and they resemble the balls used in football (soccer) and cylindrical ones are called carbon nanotubes or buckytubes (Fig 3).

2) **Nanoparticles:** are defined as particulate dispersions or solid particles with a size in the range of 10-100 nm.

* *Shapes of nanoparticles*

A- Nanorods (Fig. 4):

Typically 1-100 nm in length, nanorods are most often made from semiconducting materials and used in nanomedicine as imaging agents. Nanorods are of particular interest in a restorative context. Enamel-prism-like hydroxyapatite (HA) nanorods has been synthesized. Since they are similar to the enamel rods that make up the basic crystalline structure of dental enamel, nanorods could contribute to a practical artificial approximation of such a naturally occurring structure [14].

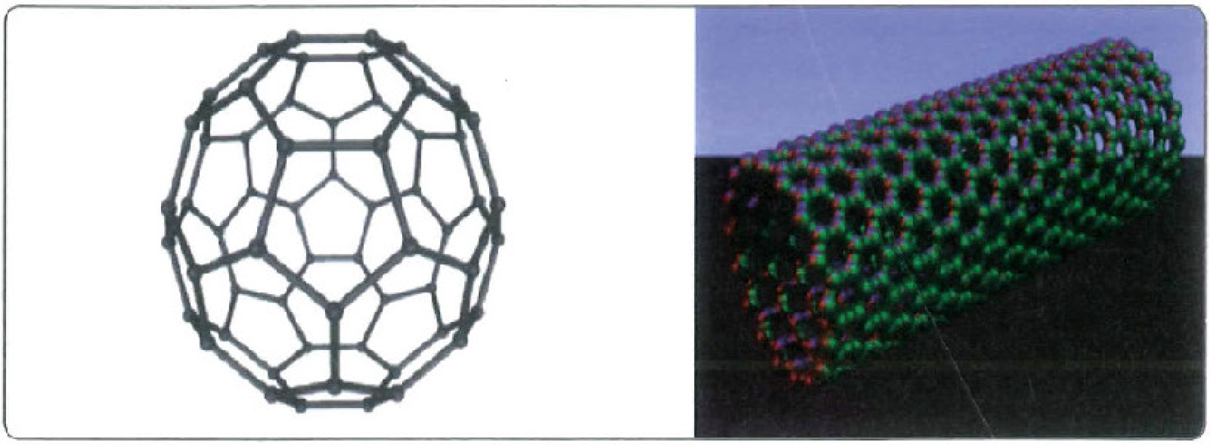
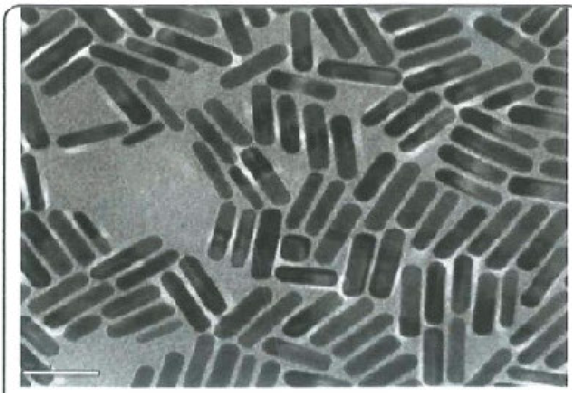


Fig. 3. Showing buckyballs and buckytubes carbon nanomaterials.



TEM image of MTAB-functionalized gold nanorods.

Fig. 4 Nanorods

B- Dendrimers and dendritic copolymers (Fig. 5):

Dendrimers are hyper-branched polymers with precise nano-architecture. Which are synthesized in a layer-by layer fashion around a core unit, resulting in a high level control of size, branching points. "Hooks" on their surfaces can be used to attach cell-identification tags, fluorescent dyes, enzymes and other molecules.

C-Quantum dots:

Also known as nanocrystals, quantum dots are nanosized semiconductors that can emit light in all colours of the rainbow. They have been applied in biotechnology for cell labeling and imaging, particularly in cancer imaging studies[15].

D- Nanoshells (Fig. 6):

Also referred to as core-shells, nanoshells are spherical cores of a particular compound surrounded by a shell or outer coating of another, which is a few nanometers thick. Upon absorbing infrared light, release a lethal dose of intense heat.

Linking nanoshells to antibodies that recognize cancer cells has successfully allowed researchers to kill cancer cells without harming neighboring non- cancerous tissue.

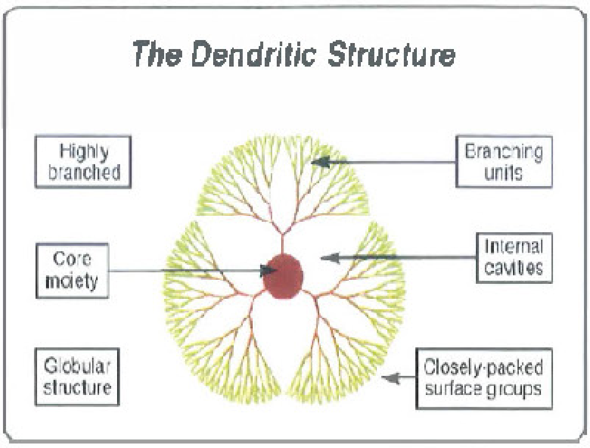


Fig. 5. Showing dendrimers

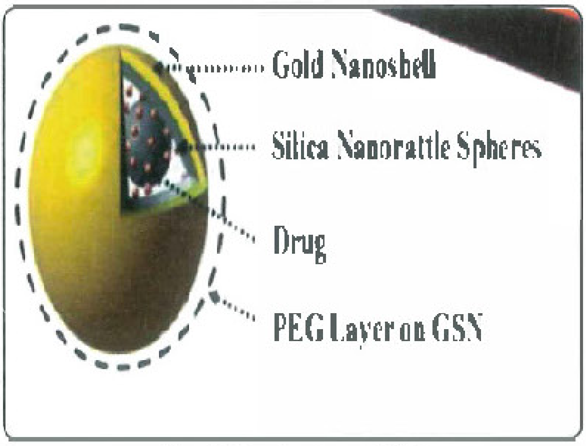


Fig. 6. Showing nanoshells

E-Liposomes:

Liposomes are lipid-based liquid crystals, formed of concentric bilayered vesicles in which an aqueous volume is entirely enclosed by a membranous lipid bilayer mainly composed of natural or synthetic phospholipids. They are used extensively in the pharmaceutical and cosmetic industries because of their capacity for breaking down inside cells once their delivery function has been met.

Liposomes were the first engineered nanoparticles used for drug delivery but problems such as their propensity to fuse together in aqueous environments, have led to replacement, or stabilization using newer alternative nanoparticles.

F- Nanocapsules (Fig. 7):

Are systems in which the drug is confined to a cavity surrounded by a unique polymer membrane, while nanospheres are matrix systems in which the drug is physically and uniformly dispersed.

- ## Different approaches to nano-fabrication

Two different approaches to nanofabrication [16,17]

-Top –down approach:

Starting material is reduced in size.

- Bottom-up or self-assembly approach:

Construction of structure atom-by-atom or molecule-by-molecule.

- ## Methods of synthesis of nanoparticles

A- physical:

1- **Attrition**: macro or micro scale particles are ground in a ball mill or other size reducing mechanism.

2- **Pyrolysis**: thermochemical decomposition of organic material at elevated temperatures then condensation on substrate surface.

- Thermal plasma torch: Delivery of the energy necessary to cause decomposition and vaporization of the material.
- Chemical vapour deposition, Hot-wire CVD (HWCVD) – also known as catalytic CVD (Cat-CVD) or hot filament CVD (HFCVD), this process uses a hot filament.
- Laser pyrolysis.

B- chemical method:

Sol-Gel:

The sol-gel process is a wet-chemical technique (also known as chemical solution deposition) widely used recently in the fields of materials science and ceramic engineering. Starting from a chemical solution (sol), which acts as the precursor for an integrated network (or gel), the gel; consists of two phases, continuous solid network phase and dispersed liquid phase.

- ## Characterization of nanoparticles [18,19]

Characterization of nanoparticles goes hand in hand with their design and production.

Particle size

Particle size and size distribution are the most important characteristics of nanoparticle

systems. They determine the in vivo distribution, biological fate, toxicity and the targeting ability of nanoparticle systems. In addition, they can also influence the drug loading, drug release and stability of nanoparticles.

Generally nanoparticles have relatively higher intracellular uptake compared to microparticles and available to a wider range of biological targets due to their small size and relative mobility. Smaller particles also have greater risk of aggregation of particles during storage and transportation of nanoparticle dispersion.

Polymer degradation can also be affected by the particle size. For instance, the rate of PLGA polymer degradation was found to increase with increasing particle size.

Surface properties of nanoparticles [20-22]

The surface electrical charges an unequal distribution between a particle surface and the solvent (fig.7). The charge density at any distance from the surface is equal to the difference in concentration of positive and negative ions. Charge density is greatest near the colloid and gradually diminished toward zero as the concentration of positive and negative ions equal each other. The surface potential is related to the surface charge. As we leave the surface, the potential drops off, the potential measured at the interface of Stern layer and the diffuse layer is defined as **zeta potential.** Changing the electrolyte concentration will destroy the electric double layer, which results in particle agglomeration.

When the potential is low, the attraction exceeds repulsion and the dispersion will aggregate. Repulsive inter-particle forces are required to prevent the agglomeration of these particles, so nanoparticles with zeta potential above (+/-) 30 mV have been shown to be stable in suspension.

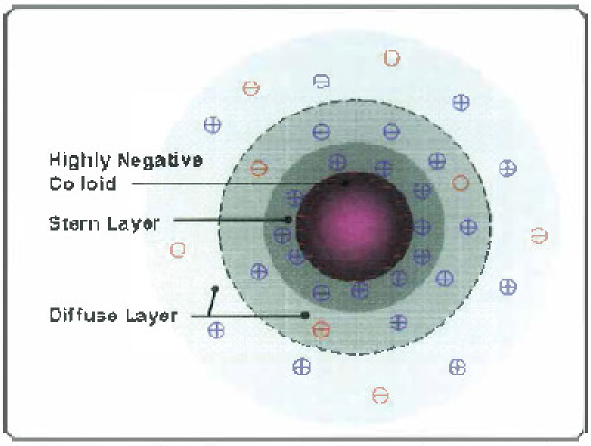


Fig. 7. Electric charge distribution in nanoparticles agglomerate.

▪ Function alization

Defined as surface coating of nanoparticles or addition of a chemical functional group on their surface in order to achieve surface modification that enables their self-organization and renders them compatible. Nanoparticles have mainly been functionalized with thiols, disulfides, amines, nitriles, car-boxylic acids, phosphines and biomolecules [23,24]. The main goal of functionalizing nanoparticles is to cover their surface with a molecule that possesses the appropriate chemical functionality for the desired application, in addition to regulate its stability, solubility and targeting.

▪ Nanotechnology in medical science

Nanometer-sized particles are in the same range of dimension as antibodies, membrane receptors, nucleic acids and proteins, among other biomolecules. These biomimetic features, together with their high surface to volume ratio, make nanoparticles powerful tools for imaging, diagnosis, and therapy [25].

- Therefore, the integration of nanomaterials with biology has led to the development of diagnostic devices, contrast agents, analytical tools, physical therapy application and drug delivery vehicles.

- Moreover, based on enhanced effectiveness, the new age drugs are nanoparticles of polymers, metals or ceramics, which can combat conditions like cancer and fight human pathogens like bacteria.
- Thus, applying nanotechnology for diagnosis, treatment, monitoring, and control of disease has been referred to as "nanomedicine"[26].

APPLICATION IN MEDICAL SCIENCE

A. *Drug Delivery System:*

For the past few decades, there has been a considerable research interest in the area of drug delivery using particulate delivery systems as carriers for small and large molecules [27].

Nanoparticles have been used as a physical approach to alter and improve the pharmacokinetic and pharmacodynamic properties of various types of drug molecules. They have been used *in vivo* to protect the drug entity in the systemic circulation, restrict access of the drug to the chosen sites and to deliver the drug at a controlled and sustained rate to the site of action.

Nanocapsules are systems in which the drug is confined to a cavity surrounded by a unique polymer membrane, while **nanospheres** are matrix systems in which the drug is physically and uniformly dispersed.

In recent years, **biodegradable polymeric nanoparticles**, particularly those coated with hydrophilic polymer such as poly (ethylene glycol) (PEG) known as long-circulating particles, have been used as potential drug delivery devices because of their ability to circulate for a prolonged period time target a particular organ, as carriers of DNA in gene therapy, and their ability to deliver proteins, peptides and genes.

Though **liposomes** have been used as potential carriers with unique advantages including protecting drugs from degradation, targeting to site of action and reduction toxicity or side effects, their applications are limited due to inherent problems such as low encapsulation efficiency, rapid leakage of water-soluble drug in the presence of blood components and poor storage stability. On the other hand, polymeric nanoparticles offer some specific advantages over liposomes. For instance, they help to increase the stability of drugs/proteins and possess useful controlled release properties.

Nanobots are robots that carry out a very specific function and are just several nanometers wide. They can be used very effectively for drug delivery. They have walls that are just 5-10 nm thick and the inner drug-filled cell is usually 50-100 nanometers wide. When they detect signs of the disease, thin wires in their walls emit an electrical pulse, which causes the walls to dissolve, and the drug to be released. The drug target a precise location which make the drug much more effective, reduce the chances of possible side effects and the time of drug release can be easily controlled [28].

- **Targeted Drug delivery** [29,30]

A key area in drug delivery is the accurately targeting of the drug to cells or tissue of choice. Drug targeting systems should be able to control the fate of a drug entering the body.

Nanoparticulate Targeting:

Nanoparticles may be delivered to specific sites by:

1. Active targeting.
2. Size dependent passive targeting

◊ **Active targeting:**

Active targeting involves the use of targeting ligands such as antibodies, peptides that bind specifically to receptors expressed on target site Some examples of targeting ligands used in nanoscale drug delivery systems include folate, transferrin.

By actively targeting nanoscale drug delivery systems it is possible to minimize the uptake of anticancer agent by normal cells thus minimizing the side effects of therapy.

◊ **Passive targeting:**

Passive targeting is the preferential accumulation of chemotherapeutic agents in solid tumors as a result of the enhanced vascular permeability of tumor tissues compared with healthy tissue. Occurs due to leaky vasculature of solid tumors.

This process is also called Enhanced Permeation and Retention effect (EPR).

B. Disease Diagnosis and Prevention:

Special sensor nanobots can be inserted into the blood under the skin where they check blood contents and warn of any possible diseases.

Nanobots can also be used to prevent heart attacks by removing fat deposits blocking the blood vessels [27].

C. Tissue Reconstruction:

Nanoparticles can be designed with a structure very similar to the bone structure. An ultrasound is performed on existing bone structures and then bone-like nanoparticles are created using the results of the ultrasound [17]. The bone-like nanoparticles are inserted into the body in a paste form [31]. When they arrive at the fractured bone, they assemble themselves to form an ordered structure, which later becomes part of the bone.

Another key application for nanoparticles is the treatment of injured nerves. Samuel Stupp and John Kessler at Northwestern University in Chicago have made tiny rod like nano-fibers called amphiphiles. They are capped with amino acids and are known to improve the growth of neurons and prevent scar tissue formation. Experiments have shown that rat and mice with spinal injuries recovered when treated with these nano-fibers [15].

D- Improved Imaging of Tumors

Quantum dots nanomaterials glow very brightly when illuminated by ultraviolet light. They can be coated with a material that makes the dots attach specifically to the molecule they want to track. Quantum dots bind themselves to proteins unique to cancer cells, literally bringing tumors to light [15].

- ## Nanotechnology and nanobiomaterials in dentistry:

New potential treatment opportunities in dentistry may include different approaches [32]:

a. Building up particles by combining atomic elements: i.e bottom-up approach. This is applied in local anesthetics, hypersensitivity cure, dentifrices, orthodontic treatment, photosensitizer and carriers in addition to diagnosis and treatment of oral cancer.

b. Construction of structure atom-by-atom or molecule-by-molecule.: i.e top-down approach.

   Examples include nanocomposites, impression materials, nanosolutions, nanoneedles, nanotweezers, and bone replacement materials

c. In addition to bottom up and top down approaches, there is the functional approach.

This approach disregards the method of production of a nanoparticle; and the objective is to produce a nanoparticle with a specific functionality [6,33].

1- Nanotechnology in periodontics [32]

A) Maintenance of oral hygiene:

- Nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all the supragingival and subgingival surfaces metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement[34] (Fig. 8).
- Aka Nanoxyd Toothpaste containing synthesized hydroxyapatite, calcium peroxide, enzymes such as (papain and bromelain), fluoride combination, Co-enzyme Q10 and Vitamin E proven useful to freshen breathe as well as whiten teeth. The risks of nanotechnology toothpaste: Nanotechnology toothpaste has been shown to be harmful because some of the nanotechnology toothpastes are made with silver hydroxyapatite [35]:

  1. If this accumulates in the tissues of people who use this toothpaste, it could cause potential health effects.
  2. Risk of nanoparticles flowing through the body if the toothpaste is actually swallowed.
  3. Some people feel that this is not friendly for the environment.
  4. They can even slip through the olfactory nerve into the brain, evading the protective blood brain barrier.

- Moreover, toothpastes containing nanosized calcium carbonate enabled remineralization of early enamel lesions as a prophylactic measure to prevent dental caries [36].

B) Drug delivery:

Nanoparticles impregnated with antimicrobial agents were produced in order to maintain therapeutic concentration of the agent in the periodontal pocket for a sufficient length of time to ensure eradication of the bacteria present [36,37]. Drug delivery systems based on triclosan-incorporated nanoparticles have been developed. Tetracycline based microspheres are also being evaluated for placement in periodontal pockets [34].

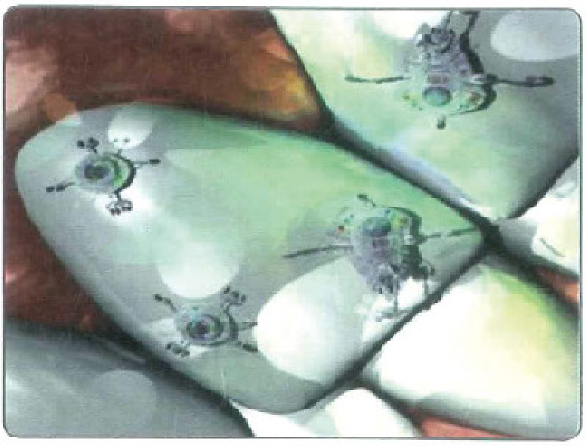


Fig. 8. Nanorobotic dentifrice

2- Nanotechnology in orthodontic treatment

Orthodontic nanorobots could directly manipulate the periodontal tissues allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours [38]. Sliding a tooth along an arch wire involves a frictional type of force that resists this movement. Use of excessive orthodontic force might cause loss of anchorage and root resorption, but coating orthodontic wire with inorganic fullerene like tungsten disulfide nanoparticles, reduction in friction has been reported [32].

3- Nanotechnology for cavity preparation and restoration:

- Nanorobots are precise and restricted to the demineralized enamel and dentin thus providing maximum conservation of the tooth structure.

- Non-agglomerated discrete nanoparticles are homogeneously distributed in resins or coatings to produce nanocomposites. Aluminosilicate nanofiller was used to produce nanocomposites with superior hardness, flexural strength, modulus of elasticity, decreased polymerization shrinkage and also have excellent handling properties [36].
- A recent study by Xu et al. has evaluated the incorporation of nanosized CaPO4 particles into resin based composites, described as "Smart" because they release calcium and phosphate ions at a cariogenic pH (8) and remineralize tooth lesions resulting in improvement in stress bearing capacity [39,40].
- **Nanotechnology in dental adhesive,** the aim of filler addition to dentin adhesives are to increase the mechanical properties and elastic modulus of adhesive layer, to improve the distribution of the stresses induced by resin composite polymerization shrinkage and occlusal loading, and consequently to increase the dentin bonding strength.
- **Glass ionomer restoration,** nanotechnology makes a better, more esthetic glass ionomer. As nanofillers and nanoclusters add benefits not usually associated with glass ionomers, it has resulted in a new category of glass ionomer restorative termed "*the nano-ionomer*".

• Nanobiomaterials and endodontics

Almost every aspect in endodontics has gained advantage of the newly emerging nanotechnology:

1- Radiography

Digital dental imaging:

Advances in digital imaging techniques are also expected with nanotechnology. In digital radiographies obtained by nanophosphor scintillators, the radiation dose is diminished and high quality images are obtained [26].

2- local anesthesia:

To induce oral anesthesia, professionals will install a colloidal suspension containing millions of active analgesic dental nanorobot particles on the patient's gingiva. Moving nanorobots reach dentin by migrating into the gingival sulcus and passing painlessly through the lamina. On reaching the dentin, the nanorobots enter dentinal tubule and proceed towards the pulp, all under the control of the onboard nanocomputer, as directed by the dentist. Nanorobots complete the journey into the pulp chamber in 100 sec. The analgesic dental nanorobots commanded by the dentist to shut down all sensitivity in the tooth that requires treatment. After the oral procedure is completed, the dentist orders the nanorobots to restore all sensation, to retract from the tooth via same path. This analgesic technique is patient friendly, as it reduces anxiety, needle phobia, and most importantly, is a quick and completely reversible action [36,41].

3- Dentin hypersensitivity:

Dentin hypersensitivity is defined as a sharp pain arising from exposed dentin as a result of various stimuli such as heat, cold, chemical or osmotic changes. It may be caused by changes in pressure transmitted hydrodynamically to the pulp.

Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure [32]. Novamin containing dentrifice (calcium sodium phospho silicate) is a bioactive glass in the class of highly biocompatible material that was originally developed as bone regenerated material, it has the ability to significantly reduce dentin sensitivity within one week compared to placebo dentrifices [42].

One of the methods of closing sub micron sized dentinal tubules involved highly concentrated gold nanoparticles that were brushed into exposed open ends of tubules [43].

4- Canal cleanliness:

Saghiri et al 2012 found that a nanostructured foam can remove debris from endodontic files, especially from those with complex morphology; where the nanostructured foam was more efficient in removing debris from RaCe and K3 than ProFile file cleaner [44].

5. **Root canal disinfection: nanoparticle-based disinfection:** Nanoparticles exhibit antibacterial activity as a result of their polycationic/ polyanionic nature with the higher surface area and charge density. The size of nanoparticles plays an important role in their antibacterial activity; smaller particles show higher antibacterial activity than the macro-scaled ones. Direct or close contact between the nanoparticles and the bacterial membrane were essential for effective destruction of bacteria [44].

Antimicrobial mechanisms of nanomaterials include:

1. Photocatalytic production of reactive oxygen species (ROS) that damage cellular and viral components.
2. Compromising the bacterial cell wall/ membrane.
3. Interruption of energy transduction.
4. Inhibition of enzyme activity and DNA synthesis.

Different types of nanomaterials like copper, zinc, titanium, magnesium, gold and silver had come up and were investigated for their antimicrobial potential against endodontic pathogens:

A. Silver nanoparticles (AgNPs):

The antimicrobial properties of AgNPs have been generally exploited in nanofiber materials, bandages, wound dressings, ointments, surgical instruments and bone prostheses that are all coated or embedded with AgNPs [45-47].

Mechanism of action:

AgNPs work in a number of ways to disrupt critical functions in a microorganism:

- Nanoparticles get attached to the cell membrane and also penetrate inside the bacteria to inactivate critical physiological functions such as cell wall synthesis, membrane transport, phosphorus containing compounds, e.g: DN [48].
- The positively charged AgNPs interact strongly with the cell membrane modifying its permeability [49, 50].
- Moreover, the AgNPs interact with multiple targets in the microbial cell, such as enzymes and plasmids, providing the bacteria with the least capacity to gain resistance [50].
- In fact, AgNPs with size in the range of 10-100 nm showed powerful bactericidal potential against both gram +ve and gram -ve bacteria.
- In an aqueous microenvironment, the silver nano-particles continuously release silver ions [47].

Wu et al, showed that E. faecalis biofilm treated with 0.2% AgNP as an intracanal medicament for 7 days was more disrupted than when treated with 0.1% AgNP irrigation solution for 7 days [50]. Moreover, a mixture of $Ca(OH)_2$ and AgNPs had a potential advantage for use as intracanal medicament for eliminating E. faecalis from root canals at 1 and 7days [51].

The surface charge on AgNPs was important in bactericidal efficacy against E. faecalis. When NPs with positive, negative, or neutral surface charges were compared; the positively charged AgNPs were effective against E. faecalis and exhibited a high level of cytocompatibility [52]. AgNP dispersion was found to be biocompatible, especially in lower concentrations [53].

Lotfi et al revealed that AgNPs in a remarkably lower concentration would possess the same reducing effect on E. faecalis as 5.25% NaOCl [54].

B- Chitosan:

Chitosan is a derivative of chitin, one of the most abundant natural polymers in the biosphere. Chitin is the main component of the exoskeleton of marine crustaceans (e.g shrimps, crabs, etc..).

Chitosan can be obtained by de-acetylation of chitin; it is a polysaccharide that possesses many useful properties. It is currently receiving a great deal of interest for medical, pharmaceutical, and agricultural applications[55], due to its biodegradability, biocompatibility, nontoxicity, and antiviral properties. These biopolymers can be easily processed into gels, sponges, membranes, scaffolds for tissue engineering, wound dressing, drug delivery and cancer diagnosis.

Although, the antibacterial effect of chitosan is not affected by the presence of dentin, dentin matrix, or lipopolysaccharide [56], its use is limited because of its insolubility in water, high viscosity, and tendency to coagulate with proteins at high pH [55].

Chitosan shows its antibacterial activity only in an acidic medium because of its poor solubility above pH 6.5 [55]. Yeasts and moulds are the most sensitive group, followed by gram-positive bacteria and finally gram-negative bacteria.

Shrestha et al, investigated the efficacy of collapsing cavitation bubbles to deliver the antibacterial chitosan nanoparticulates into dentinal tubules to improve root canal disinfection. The collapsing cavitation bubbles treatment using high-intensity focused ultrasound resulted in significant penetration up to 1000 μm of the antibacterial chitosan nanoparticulates into the dentinal tubules [57].

Mechanism of action:

1. Binding to the negatively charged bacterial surface causing agglutination, increasing the permeability of the microbial wall, which eventually induces a leakage of intracellular components.
2. According to another proposed mechanism, chitosan chelates trace metal and thereby inhibits enzyme activities and the microbial growth.
3. It was also proposed that chitosan penetrates to the nucleus of fungi and inhibits RNA and protein syntheses.
4. The lower molecular weight chitosans have greater antimicrobial activity than native chitosans. Highly de-acetylated chitosans are more antimicrobial than those with a higher proportion of acetylated amino groups.
5. The temperature has an effect; higher temperature (37°C) has been shown to enhance antimicrobial activity compared to refrigeration temperatures.
6. Positively charged chitosan nanoparticulates in an aqueous suspension are allowed to settle onto a substrate surface and adhere to negatively charged dentin surface [58].

C- Zinc oxide NPs (ZnONPs):

Kishen et al, investigated the antibacterial and antibiofilm efficacy of cationicnanoparticles (zinc oxide nanoparticles and chitosan nanoparticles) for root canal disinfection. The incorporation of nanoparticles did not alter the flow characteristics of the sealer but improved the direct antibacterial property and ability to leach out of the antibacterial component with significant reduction in adherence of E.faecalis to treated dentin [53].

Mechanism of action:

The antibacterial activity of the polycationic ZnONPs were attributed to the electrostatic

attraction with the negatively charged bacterial cell, which might lead to the altered cell wall permeability, resulting in leakage of the proteinaceous and other intracellular components and death of the cell [44].

D. Photodynamic therapy (PDT)/photosensitizers:

The recent advances toward achieving predictable endodontic disinfection have focused on newer alternatives such as PDT.

PDT is based on the injection, ingestion, or topical application of photosensitizer dyes followed by visible light activation [56, 59, 63].

• *There are two types of PDT mechanism [61]:*

Type I: It involves the production of free radical, which react with oxygen, resulting in production of highly reactive oxygen species (ROS).

Type II: It involves the production of highly reactive oxygen known as singlet oxygen.

Mechanism of action:

- PDT uses a specific wavelength of light to activate a non-toxic dye (photosensitizer), leading to the formation of ROS and singlet oxygen.
- These ROS or singlet oxygen molecules are highly reactive, and damage bacterial cell wall, membrane lipids and proteins, and nucleic acids, which promote bacterial cell death [55,62].
  - ◊ *Advantage:* broad-spectrum antibacterial activity.
  - ◊ *Disadvantage:* The reduction in the uptake of the photosensitizers into the bacterial cells and the multidrug resistance pumps in bacteria which decrease the effectiveness of the photosensitizer could be of the clinical factors in compromising the antibacterial effect of PDT [56,59].
- Moreover, the antibacterial activity of PDT was compromised in the presence of root canal constituents such as pulpal tissue, serum, dentin matrix, and bacterial remnants [63].

* **Photosensitizers** [64]:

Phenothiazines and xanthenes are 2 classes of photosensitizers commonly tested for antibacterial efficacy [56].

1. **Rose Bengal (RB)** is an anionic xanthene dye [55].
   - Advantages: Water soluble, nontoxic, and it adsorbs light in the visible spectral region [66].
   - Disadvantage: Its application is strongly limited by the fact that it tends to aggregate in aqueous solutions.
2. **Methylene blue (MB)** is a well-established photosensitizer that falls under the category of cationic phenothiazines [56] and has been used in PDT for targeting various gram positive and gram-negative oral bacteria.
   - MB possesses a greater antibacterial effect than RB because of its hydrophilicity, low molecular weight, and cationicity [56]
   - *Disadvantage:* The reduced susceptibility of biofilms to PDT was attributed to reduced penetration of the photosensitizer.

* **Functionalization/Conjugation:**

Coating or surface attachment of photosensitizers to nanoparticles significantly improved antibacterial properties [63].

Functionalize nanoparticles with photosensitizers offer unique physicochemical advantages such as allowing higher concentration of photosensitizer uptake per cell, reduce the efflux of photosensitizer from target cell, permit greater interaction with cells because of the surface charge, provide greater stability to photosensitizer molecules after conjugation and allow control release of reactive oxygen species [60,63].

- Chitosan offered an attractive material for conjugation with other reactive molecules. This was attributed to the membrane destabilizing/ permeabilizing effect that could subsequently enhance the effect of singlet oxygen on bacterial cells [65]. In fact, the antibacterial effect of PDT was significantly improved when chitosan was conjugated with rose bengal, even in presence of tissue inhibitors (dentin, dentin matrix, lypopolysaccharides) [55].
- The effect of poly (lactic- co-glycolic acid) (PLGA) nanoparticles loaded with MB and light against E. faecalis was observed by transmission electric microscope and revealed substantial accumulation of nanoparticles on bacterial cell walls of microorganisms with reduction of colony-forming units (CFUs) in planktonic phase and root canals wall, respectively [60].

E. Nanoparticles of gold and silver: (NANOCARE PLUS)

NanoCare Plus is based on silver and gold nano particles, low surface tension of the nanoparticles allows them to get to the smallest fissures and dental ducts of the system, it has strong bacteriostatic effect, eliminate E. Faecalis [67] and prevent the re-colonization of canal system by bacteria and fungi by leaving a layer of long lasting nanoparticles on the canals surface so it can be used as final rinsing at the root canal treatment.

Nanoparticles of gold and silver does not undergo corrosion process due to their minimum concentration in the liquid that allows, also, the avoidance of any problems during the final root canal filling followed by tooth restoration.

6. Vital pulp therapy:

Vital pulp therapy is aiming at treating injuries by pulp capping to seal the pulp, stimulating the formation of tertiary dentin, and maintaing pulp vitality.

- Compared to regular bioactive glass (BG), the nano-sized BG can induce differentiation and mineralization of human dental pulp cells *in vitro* [68].
- Testing nanocrystalline hydroxyapatite (HA) paste as pulpotomy and pulp capping agent, it was found biocompatible and superior to formocresol[69]. It was also recommended as substitute for MTA and Dycal in direct pulp capping [70].

7. Regenerative Endodontics:

Tissue repair or regeneration is a complex cascade of multistep events that involves stem cells, scaffolds, and growth factors.

I- Nanoscale three-dimensional scaffolds for tissue engineering

Collagen-based nanocomposite incorporating nanobioactive glass (Col/nBG) was developed as a scaffolding matrix for dentin–pulp regeneration. It induced growth and differentiation of human dental pulp cells (hDPCs) more effectively than Col alone, providing a promising scaffold condition for regeneration of dentin–pulp complex tissue.[71]

II-Delivery system: Controlled Release of Specific Growth Factors

A well-controlled release system of specific growth factors is a pivotal strategy in dentin-pulp engineering. The different delivery systems share the same goal, which is the release of bio active molecules in a time-controlled manner.

Numerous studies focused on creating appropriate delivery systems such as NPs, micro spheres, hydrogels, and scaffolds for tissue regeneration. [72]

A-Temporal-controlled Release of Bovine Serum Albumin (BSA) from Chitosan Nanoparticles

The idea was the release of bioactive molecules in a time-controlled manner. The increase in efficacy, bioavailability and cell/tissue targeting of such molecules and protecting them from early loss of their biological activity.

** Approaches used for incorporation of active molecules in nanoparticles:

1. The encapsulation technique involves embedding and entrapping of bioactive molecules in nanoparticles matrix.
2. In the adsorption technique, the bioactive molecules are solely adsorbed to the surface of nanoparticles thus, the interaction is weak.

B- Antibiotic-containing Nano fibrous scaffolds for regenerative endodontics

Bottino et al [73] described a new antibiotic containing Nano/micro fibrous scaffolds to provide drug delivery system to disinfect necrotic immature permanent teeth through controlled release of low antibiotics dose which provide a bacteria-free environment conducive to tissue regeneration, minimizing the adverse effects of the antibiotic paste.

Fioretti et al, reported the first use of nanostructured multilayered films containing α-MSH (melanocortin peptides) I as a new active biomaterial for endodontic regeneration. They reported that α-MSH possess anti-inflammatory properties; inhibit the production and activity of pro inflammatory mediators such as IL- 1, TNF-α, IL-6, IL-13, also, induce the production of the anti- inflammatory cytokine, such as IL-10 and promote the proliferation of pulpal fibroblasts[74].

Although tooth enamel, cementum, and bone are composed of organized assemblies of carbonated apatite crystals, enamel is unusual in that it does not contain collagen and does not remodel. Self-assembly of amelogenin protein into nanospheres has been recognized as a key factor in controlling the oriented and elongated growth of carbonated apatite crystals during dental enamel biomineralization [32].

8. Endodontic filling materials:

- Nano Ag-gutta percha has been developed to improve the antibacterial effect of gutta percha [76] and several studies showed similar cytotoxity to normal gutta percha[77].
- The incorporation of nanoparticles decreased the viscosity of endodontic sealers, leading to enhanced flow.
- Javidi et al, reported that synthesized ZnO nano-powder sealers was suitable for use as a nano-sealer in root canal therapy to prevent leakage [77].
- CS/ZnO nanoparticles mixed to zinc oxide eugenol (ZnOE) sealer displayed the ability to leach out antibacterial components and reach deep into the dentinal tubules [58]. Furthermore, incorporating CSNPs into the ZnOE sealer inhibited biofilm formation within the sealer/dentin interface [78].
- Incorporation of insoluble antibacterial quaternary polyethylenimine NPs into AH Plus and GuttaFlow led to significant and stable antimicrobial properties of both sealers [79].
- Recently the School of Dental Sciences, University Sains Malaysia, has prepared a new experimental endodontic sealer (Nanoseal). This sealer is similar to various epoxy resin-based sealers, but with a HA nanofiller. Reactive nano particles can slow down the growth of bacteria and this in turn accelerates the process of recovery of infected teeth. The size of the active nano particles can enter the accessory canals to ensure that all the spaces have been sealed effectively. Besides the nano size, the similarity between the structure of the material with that of the teeth also increases the biocompatibility between the material and the teeth, thereby increasing its adhesive strength [80].

9. Endodontic surgery:

a) Root end filling materials:

- Chogle et al found that the addition of nanoparticles to monomer matrix of root end filling materials reduced apical leakage significantly [81].
- The cytotoxicity of a polymer nanocomposite resin was not significantly different from that of ProRoot MTA and Geristore [82].
- Akbari et al found that the addition of nanosilica to MTA accelerated the hydration process, reduced the setting time, and had no adverse effect on the compressive and flexural strength of MTA[83].
- White MTA, bioaggregate, and nano white MTA showed high solubility in acidic pH. However, nano white MTA cement was capable of producing lower porosity in set materials, better hydration and strength even in acidic environment [84].
- Samiei et al found that the addition of AgNPs to MTA improved its antimicrobial efficacy [85].

b) Bone replacement materials:

- Nanosized HA is the main component to mineral bone in the form of nanometer sized needle-like crystals of approximately 5-20nm width by 60nm length.
- Utilizing nanotechnology, Ca and phosphate are manipulated at the molecular level and assembled to produce a strong and osteoconductive material with unique structural and functional properties [32].
- Nanosized hydroxyapatite (HA) is the main component of mineral bone. Synthetic HA possesses exceptional biocompatibility and bioactivity properties with respect to bone cells and tissues, hence, it has been widely used clinically in the form of powders, granules, dense and porous blocks and various composites. Nanophase HA properties such as surface grain size, pore size, wettability, etc, could control protein interactions modulating subsequent enhanced osteoblast adhesion and long-term functionality. However, since nanophase materials can mimic the dimensions of constituent components of natural tissues, several reports on nanophase materials encourage its use for tissue engineering applications [86,87].

10. Temporization:

- Quaternary ammonium polyethyleneimine (QPEI) nanoparticles are long-lasting, stable, biocompatible, and nonvolatile antibacterial polymers.
- Incorporation of QPEI NPs into standard temporary restorative materials improved significantly their sealing ability and antibacterial properties [88].

11. Dentin stabilization

- PDT may enhance cross-linking of collagen fibrils in the dentin matrix and thereby improve dentin stability [62].
- Likewise, chitosan may increase the resistance of collagen to enzymatic degradation; and chitosan composites with collagen could reinforce the collagen constructs.
- Chitosan nanoparticles (CSNPs) and PDT inhibit the activity of bacterial collagenases. Thus, PDT and binding to CSNPs inhibit bacterial-mediated collagenolytic activity and enhance the mechanical properties of collagen matrix[76]. The Photo-activation of bioactive polymeric chitosan nanoparticles functionalized with rose-bengal, resulted in crosslinking of dentin-collagen and incorporation of CS nanoparticles within the collagen architecture. Which improved mechanical properties, reinforced the collagen structure by increasing the number of amine reaction sites, resulting in the formation of ionic complexes between CS and collagen during crosslinking [89].

** However, the same properties that make nanoparticles so unique - that is, primarily, their small size, large surface area, chemical composition, solubility, and geometry - could also be responsible for their potential hazard to human health.

• Problems with using Nanotechnology:

A- *Environmental problems :*

The greatest risk to the environment lies in the rapid expansion and development of nanoparticles using large-scale production[90]. Nanoparticles have a tendency to form aggregates that are very water soluble and bactericidal and that can be catastrophic as bacteria are the foundation of the ecosystem. Scientists also fear that nanoparticles may damage the ozone layer[28].

B - *Health problem:*

The risk of nanoparticles to the health of human beings is of far greater concern. James Baker, director of the Center for Biologic Nanotechnology at the University of Michigan, says "Any time you put a material into something as complex as a human being, it has multiple effects"[23]. Nanoparticles are likely to make contact with the body via the lungs, intestines and skin.

1. ***Risk to lungs:*** Nanoparticles are very light and can easily become airborne. They can easily be inhaled during the manufacturing process where dust clouds are a common occurrence. Particles passing into the walls of air passage can worsen existing air disease such as asthma and bronchitis and can be fatal[91].
2. ***Effects on brain:*** Some nanoparticles that are inhaled through the nose can move upward into the base of the brain. This may damage the brain and the nervous system and could be fatal[90].
3. ***Problems in blood:*** Nanoparticles flowing through the bloodstream may affect the clotting system, which may result in a heart attack. If these nanoparticles travel to organs like the heart or the liver, they may affect the functionality of these organs[90].

C. *Feasibility Problems*

1- Expense:

Conducting research on nanotechnology is very expensive. An article in the Nanotech Report 2004 claimed that global investment on nanotechnology has reached: $8.6 billion; total investment. At present the tools for developing nanotechnology are very basic and we still need more investment to reap the benefits of this great technology.

2. Lack of knowledge and research:

Money is not the only problem. There is a lack of qualified individuals who can research and develop the technology. Many of the methods and tools needed to characterize nanomaterials are still in a very early stage of development. A nation wide survey from North Carolina University found that around 80% of Americans knew nothing about nanotechnology[28].

D. *Ethical dilemma:*

The most important feature of nanotechnology is that it gives us control over individual molecules. Every patho-physiological process has a molecular origin, and it is from this basic fact that the [tremendous potential of nanotechnology to medicine arises][91]. Scientists believe that nanotechnlogy could give man a better quality of life, power to prevent diseases, speed up tissue reconstruction and alter his genetic sequence. Unfortunately these promises are coupled with ethical implications, which must be considered, if not resolved before the field of nanotechnology reaches its fullest potential.

The question arises, *Who is in control?* Nanotechnology introduces things that are not natural or foreseen, such as genetically modified organisms. At this point there is no established system to regulate nanotechnology and there is no specific entity to control it. With the ability to identify and manipulate specific genetic sequences, people will seek the effects of good genes. People are already using this technology to modify their unborn children to have the right hair or eye color. ***In doing this people risk losing their individuality.***

No doubt the benefits of this technology are innumerable but before taking any step we should think about the implications and the focus should be on developing a safe nanotechnology industry.

CHAPTER REVIEW QUESTIONS

- Define nanotechnology
- Cite the properties of nanoparticles.
- List the possible applications of nanotechnology in endodontics.
- Correlate the special properties of nanoparticles to their applications in endodontics.
- How did functionalization improve the antimicrobial action of photodynamic therapy?

REFERENCES

1. ***Feynman RP.*** There's Plenty of Room at the Bottom. Reinhold, New York (1961).
2. ***Aniguchi N.*** On the Basic Concept of Nano Technology, Proceeding of International Conference on Production Engineering. JSPE 1974; 2: 18-23.
3. ***Kaehler T.*** Nanotechnology: Basic Concepts and Definitions. Clinical Chemistry 1994; 40: 1797-1799.
4. ***Donaldson, Ken, Vicki Stone.*** "Nanoscience Fact Versus Fiction." Association for Computing Machinery (2004): 1: 3.
5. ***Mohan S, Gurtu A, Singhal A, Mehrotra A.*** Nanotechnology: Its implications in conservative dentistry and endodontics. J Dent Scie and Oral Rehab 2013.
6. ***Sivaramakrishnan SM, Neelakantan P.*** Nanotechnology in Dentistry - What does the future hold in store? Dentistry 2014; 4: 198.
7. ***Shrivastava S, Bera T, Roy A, Singh G, Ramachandrarao P, dash D.*** Characterization of enhanced antibacterial effects of novel silver nanoparticles. Nanotechnology 2007; 18: 1– 9.
8. ***Roszek B, Jong WH, Geertsma RE.*** Nanotechnology in medical applications: state-of-the-art in materials and devices. RIVM report 265001001/2005.
9. ***Wiese GR, Healy TW.*** Trans. Faraday Soc. 1970; 66:490.
10. ***Miller KT, Zukoski CF.*** Semiconductor Nanoparticles, Physical, Chemicaland Catalytic Aspects, Elsevier 1948; 23-57.
11. ***Sanvicens N, Marco MP.*** Multifunctional nanoparticles-properties and prospects for their use in human medicine. Trends Biotechnol. 2008; 26: 425-33.
12. ***Freitas RA.*** Nanomedicine. Basic Capabilities, Georgetown, TX: Landes Bioscience 1999; 1:345-347

13. *Iijima S, Brabec C, Maiti A*. Structural flexibility of carbon nanotubes. J Chem and Physiol 1996; 104: 2089-2092.

14. *Chen H, Clarkson BH, Sun K, Mansfield JF*. Self assembly of synthetic hydroxyapatite nanorods into an enamel prism-like structure. J Colloid Interface Sci 2005; 288: 97–103.

15. *Weiss, Rick*. "Nanomedicine's Promise Is Anything but Tiny." Washington Post 2005: 1-3. <http://www.washingtonpost.com/wp-dyn/articles/A49758 2005Jan30.html> (8 Nov. 2006).

16. *Freitas RA*. Nanotechnology, nanomedicine and nanosurgery. Int J Surg. 2005;3:243-6.

17. *Silva, Gabriel A*. "Introduction to Nanotechnology and Its Applications to Medicine." Surgical Neurology 2004 216-220 <http:// www.sciencedirect.com/view?=cchp87-a2article.pdf> (5 Nov. 2006).

18. *Joshi M, Bhattacharyya A, Ali WS*. Characterization techniques for nanotechnology application in textiles. Indian J Fiber and texti resc 2008; 33:304 17.

19. *Pagonis TC, Chen J, Fontana CR, Devalapally B, Ruggiero K, Song X, Foschi F, Dunham J, Skobe Z, Yamazaki H, Kent R, Anne C.R. Amiji MM, Soukos MS*. Nanoparticle-based Endodontic Antimicrobial Photodynamic Therapy. J Endod 2010;36:322 328.

20. *Gouy J*. Phys. Chem. 1910; 9: 45.

21. *Chapman DL*. Philos. Mag. 1913; 25,475

22. *Stern OZ*. Electrochemistry, 1924; 30,:508.

23. *Roux S, Garcia B, Bridot JL, Salome M, Marquette C, Lemelle L, Gillet P, Blum L, Perriat P, Tillement O*. Synthesis and characterization of dihydrolipoic acid capped gold nanoparticles and functionalization by the electroluminescent luminal. Langmuir 2005; 21:2526-2536.

24. *Woehrle G H, Hutchison J E*. Thiol-functionalized undecagold clusters by ligand exchange: Synthesis, mechanism, and properties. Inorg. Chem 2005; 44: 6149-6158.

25. *Sanvicens N, Marco MP*. Multifunctional nanoparticles-properties and prospects for their use in human medicine. Trends Biotechnol. 2008; 26:425-33.

26. *Ozak ST, Ozkan P*. Nanotechnology and dentistry. Eur J Dent 2013; 7: 145-51.

27. *Harry R*. "Micro and Nanotechnology-The Next Big Tiny Thing?" Mercer Business.2005;1-4<http://findarticles.com/p/ articles/mi_qa3697/is_200501/ai_n9521342> (12 Nov. 2006)

28. *Perkel, Jeffrey M*. "The Ups and Downs of Nanobiotech." The Scientist. 2004: 1-8 <http://www.the-scientist.com/2004/08/30/14/1> (12 Nov. 2006).

29 *Agnihotri J, Saraf S, Khale A*. Targeting:new potential carriers for targeted drug delivery sysyem. 2011; 8: ISSN 0976 – 044X (Article).

30. *Bae UH, Park K*. Targeted drug delivery to tumors: Myths, reality andpossibility. J Contro Relea 2011; 153: 198 205

31. *Dhikari, Raju*. "Nanobiotechnology: Will It Deliver?" Healthcare Purchasing News 2005: 1-3 <http://findarticles.com/p/ articles/mi_m0BPC/is_1_29/ai_n8708476> (12 Nov. 2006).

32 32- *Mohan S, Gurtu A, Singhal A, Mehrotra A*. Nanotechnology Its Implications in Conservative Dentistry and Endodontics. J of Dent Scie and Oral Reha 2013 9-3

33. *Rodgers P*. Nanoelectronics. Nature Nanotech. 2006.

34. *Ling X K*. Nanotechnology and its role in the management of periodontal diseases. Periodon 2000; 40:184–196.

35. Future of Nanotechnology Toothpaste Nanodentistry Archive for category Nanotechnology Toothpaste.

36. *Freitas RA*. Nanodentistry. J Am Dent Assoc 2000; 131: 1559-1565.

37. *Ozak ST, Ozkan P*. Nanotechnology and dentistry. Eur J Dent 2013; 7 145-51.

38. 38- *Séguier S, Souza SL, Sverzut AC, Simioni AR, Primo FL, Bodineau A, Corrêa VM, Coulomb B, Tedesco AC*. Impact of photodynamic therapy on inflammatory cells during human chronic periodontitis. J Photochem Photobiol B 2010; 101: 348-54.

39. *Xu HH, Sun L, Weir MD, Takagi S, Chow LC*. Effects of incorporating nanosized calcium phosphate particles on properties of whisker-reinforced dental composites. J Biomed Mater Res B Appl Biomater 2007; 81:116-125.

40. *Pratap R*. Engaging Private Enterprise in nanotechnology research in India. ICS, Trieste 2005.

41. *Freitas RA*. Nanotechnology, Nanomedicine and Nanosurgery. Int J Surg 2005; 3: 243-245.

42. *Marini I, Checchi L, Greenspan D*. Pilot clinical study evaluating efficacy of NovaMin containing dentifrice for relief for relief of dentin hypersensivity. NovaMin Research Report 2002.

43. *Bhardwaj SB, Mehta M, Gauba K*. Nanotechnology: Role in dental biofilms. Indian J Dent Res 2009; 20 511-513.

44. *Saghiri MA, Karamifar K, Mehrvarzfar P, Asgar K, Gutmann JL, Lotfi M, Garcia-Godoy F*. The efficacy of foam cleaners in removing debris from two endodontic instruments. Quintessence Int 2012; 43: 811-7

45. *Cohen MS, Stern JM, Vanni AJ, Kelley RS, Baumgart E, Field D. In vitro* analysis of a nanocrystalline silver-coated surgical mesh. Surg. Infect 2007; 8: 397-403.

46. *Chen J, Han CM, Lin XW, Tang ZJ, Su SJ*. Effect of silver nanoparticle dressing on second degree burn wound. Zhonghua Wai. Ke. Za. Zhi. 2006 ;44: 50-52.

47. *Chen X, Schluesener HJ*. Nanosilver: A nanoproduct in medical application. Toxicol. Lett 2008; 176: 1-12.

48. *Schreurs WJ, Rosenberg H*. Effect of silver ions on transport and retention of phosphate by *Escherichia coli*. J. Bacteriol 1982; 152: 7 13.

49. *Simon-Deckers A, Brun E, Gouget B, Carrière M, Sicard-Roselli C*. Impact of gold nanoparticles combined to X-Ray irradiation on bacteria. Gold Bulletin 2008; 41: 187-194

50. *Wu D, Fan W, Kishen A, Gutmann JL, Fan B*. Evaluation of the antibacterial efficacy of silver nanoparticles against Enterococcus faecalis biofilm. J Endod 2014; 40 285-90.

51. *Javidi M, Afkhami F, Zarei M, Ghazvini K, Rajabi O*. Efficacy of a combined nanoparticulate/calcium hydroxide root canal medication on elimination of Enterococcus faecalis. Aust Endod J 2014; 40: 61-5.

52. *Abbaszadegan A, Nabavizadeh M, Gholami A, Aleyasin ZS, Dorostkar S, Saliminasab M, Ghasemi Y, Hemmateenejad B, Sharghi H*. Positively charged imidazolium-based ionic liquid-protected silver nanoparticles: a promising disinfectant in root canal treatment. Int Endod J 2014 Epub doi: 10.1111/iej.12377.

53. *Gomes-Filho JE, Silva FO, Watanabe S, Cintra LT, Tendoro KV, Dalto LG, Pacanaro SV, Lodi CS, de Melo FF*. Tissue reaction to silver nanoparticles dispersion as an alternative irrigating solution. J Endod 2010; 36: 1698-702.

54. **Lotfi M, Vosoughhosseini , Ranjkesh B , Khani , Saghiri and Zand Z.** Antimicrobial efficacy of nanosilver, sodium hypochlorite and chlorhexidine gluconate against *Enterococcus faecalis* African Journal of Biotechnology 2011; 10 : 6799 6803

55. *Rabea EI, Badawy ME, Stevens CV, Smagghe G, Steurbaut W*. Chitosan as antimicrobial agent: applications and mode of action. Biomacromolecules 2003; 4: 1457-65.

56. *Shrestha A, Kishen A*. The effect of tissue inhibitors on the antibacterial activity of chitosan nanoparticles and photodynamic therapy. J Endod 2012; 38: 1275-8

57. *Shrestha A, Fong S, Khoo B, Kishen A*. Delivery of Antibacterial Nanoparticles into Dentinal Tubules Using High-intensity Focused Ultrasound. J Endod 2009;35 1028-133.

58. *Kishen A, Shi Z, Shrestha A, Neoh KG*. An investigation on the antibacterial and antibiofilm efficacy of cationic nanoparticulates for root canal disinfection. J Endod 2008; 34: 1515-20

59. *Séguier S, Souza SL, Sverzut AC, Simioni AR, Primo FL, Bodineau A, Corrêa VM, Coulomb B, Tedesco AC*. Impact of photodynamic therapy on inflammatory cells during human chronic periodontitis. J Photochem Photobiol B 2010; 101: 348-54.

60. *Pagonis TC, Chen J, Fontana CR, Devalapally H, Ruggiero K, Song X, Foschi F, Dunham J, Skobe Z, Yamazaki H, Kent R, Tanner AC, Amiji MM, Soukos NS*. Nanoparticle-based endodontic antimicrobial photodynamic therapy. J Endod 2010; 36: 322-8

61. *Khandage NV, Pradhan S, Doshi Y, Kulkarani A, Dhruva I*. Photodynamic therapy Part I: Application in dentistry. Int J las Dent 2013;3:7 13.

62. *Persadmehr A, Torneck CD, Cvitkovitch DG, Pinto V, Talior I, Kazembe M, Shrestha S, McCulloch CA, Kishen A.* Bioactive chitosan nanoparticles and photodynamic therapy inhibit collagen degradation in vitro. J Endod 2014; 40: 703-9.

63. *Shrestha A, Kishen A.* Antibacterial efficacy of photosensitizer functionalized biopolymeric nanoparticles in the presence of tissue inhibitors in root canal. J Endod 2014; 40: 566-70.

64. **Alexandra B, Ormond, Harold S, Freeman.** Dye Sensitizers for Photodynamic Therapy. Materials 2013; 6:17-840.

65. *Shrestha A, Kishen A.* Antibiofilm efficacy of photosensitizer- functionalized bioactive nanoparticles on multispecies biofilm. J Endod 2014; 40: 1604-10.

66. *Moczek L, Nowakowska M.* Novel water-soluble photosensitizers from chitosan. Biomacromolecules 2007; 8: 433-8.

67. *Bendnarski M, Czop A, Zarzycka B, Ebert J, Pawlicka H.* NanoCare Plus SilverGold Care eliminate Enterococcus faecalis from dentinal tubules. Dent Med. Probl. 2013; 50:418-23.

68. *Gong W, Huang Z, Dong Y, Gan Y, Li S, Gao X, Chen X.* Ionic extraction of a novel nano-sized bioactive glass enhances differentiation and mineralization of human dental pulp cells. J Endod 2014; 40: 83-8.

69. *Shayegan A, Atash R, Petein M, Abbeele AV.* Nanohydroxyapatite used as apulpotomy and direct pulp capping agent in primary pig teeth. J Dent Child (Chic). 2010; 77: 77-83.

79. *Swarup SJ, Rao A, Boaz K, Srikant N, Shenoy R.* Pulpal response to nanohydroxyapatite, mineral trioxide aggregate and calcium hydroxide when used as a direct pulp capping agent: an in vivo study. J Clin Pediat Dent 2014; 38: 201 - 6.

71. *Bae W, Min KS, Kim jj, Kim jj,Kim HW, Kim EC.* Odontogenic responses of human dental pulp cells to collagen/ nanobioactive glass nanocomposites. Dent J 2012; 28:1271-1279.

72. *Shrestha S, Diogenes A, Kishen A.* Temporal-controlled release of bovine serum albumin from chitosan nanoparticles: effect on the regulation of alkaline phosphatase activity in stem cells from apical papilla. J Endod 2014; 40: 1349-54.

73. *Bottino MC, Kamocki K, Yassen GH, Platt JA, Vail MM, Ehrlich Y, Spolnik KJ, Gregory RL.* Bioactive nanofibrous scaffolds for regenerative endodontics. J Dent Res 2013; 92: 963-9.

74. *Fioretti F, Mendoza C, Helms M, Richert L, Arntz Y, Garnier F, Haikel Y, Gangloff SC, Benkirane N.* Nanostructured assemblies for dental application. ACS Nano 2010; 4: 3277-87.

75. *Corrêa JM, Mori M, Sanches HL, da Cruz AD, Poiate Jr. E, Poiate IVP.* Silver nanoparticles in dental biomaterials. Int J Biomat 2015; article 485275.

76. *Shantiaee Y,Dianat H, Khani M, Baghban A.*Cytitixicity comparison of silver coated gutta-percha with Gutta flow and normal gutta percha on L929 fibroblast with MTT assay. Beheshti Univ Dent J 2011;29:62-68.

77. *Javidi M, Zarei M, Naghavi N, Mortazavi M, Nejat AH.* Zinc oxide nanoparticles as sealer in endodontics and its sealing ability. Contemp Clin Dent 2014; 5: 20-4.

78. *DaSilva L, Finer Y, Friedman S, Basrani B, Kishen A.* Biofilm formation within the interface of bovine root dentin treated with conjugated chitosan and sealer containing chitosan nanoparticles. J Endod 2013; 39: 249–53.

79. *Kesler Shvero D, Abramovitz I, Zaltsman N, Perez Davidi M, Weiss EI, Beyth N.* Towards antibacterial endodontic sealers using quaternary ammonium nanoparticles. Int Endod J 2013; 46: 747-54.

80. *Aal-Saraj AB, Ariffin Z, Masudi SM.* An agar diffusion study comparing the antimicrobial activity of Nanoseal with some other endodontic sealers. Aust Endod J 2012; 38: 60-3.

81. *Chogle SM, Duhaime CF, Mickel AK, Shaikh S, Reese R, Bogle JH, Chan DK, Potluri S, Qutubuddin S.* Preliminary evaluation of a novel polymer nanocomposite as a root-end filling material. Int Endod J 2011; 44: 1055-60.

82. *Modareszadeh MR, Chogle SA, Mickel AK, Jin G, Kowsar H, Salamat N, Shaikh S, Qutbudin S.* Cytotoxicity of set polymer nanocomposite resin rootend filling materials. Int Endod J 2011; 44: 154-61.

83. *Akbari M, Zebarjad SM, Nategh B, Rouhani A.* Effect of nano silica on setting time and physical properties of mineral trioxide aggregate J Endod 2013; 39:1448-51.

84. *Saghiri MA, Godoy FG, Gutmann JL, Lotfi M, Asatourian A, Sheibani N, Elyasi M.* The effect of pH on solubility of nano-modified endodontic cements. J Conserv Dent 2014; 17: 13-7.

85. *Samiei M, Aghazadeh M, Lotfi M, Shakoei S, Aghazadeh Z, Vahid Pakdel SM.* Antimicrobial efficacy of mineral trioxide aggregate with and without silver nanoparticles. Iran Endod J 2013; 8: 166 - 70.

86. *Verma SK.* A critical review of the implication of nanotechnology in modern dental practice. National J of oral maxillofacial surgery. 2010; 1 1:41-44.

87. *Paul W, Sharma CP.* Nanoceramic Matrices: Biomedical Applications. Am J Biochem Biotech 2006;2(2):41-48.

88. *Abramovitz I, Beyth N, Paz Y, Weiss EI, Matalon S.* Antibacterial temporary restorative materials incorporating polyethyleneimine nanoparticles. Quintessence Int 2013; 44: 209-16.

89. *Sionkowska A, Wisniewski M, Skopinska J, Kennedy CJ, Wess TJ.* 641 Molecular interactions in collagen and chitosan blends. Biomaterials 642, 2004;25:795-801.

90. *Donaldson, Ken, Vicki S.* "Nanoscience Fact Versus Fiction." Association for Computing Machinery (Nov. 2004): 113

91. *Silva, Gabriel A.* "Introduction to Nanotechnology and Its Applications to Medicine." Surgical Neurology 61.3 (Mar. 2004): 216-220. <http// www.sciencedirect.com/view?=cchp87-a2article.pdf> (5 Nov. 2006)

34 Evidence-Based Endodontics

TECHNICAL & CLINICAL ENDODONTICS

Suzan Abdul Wanees Amin

Intended Learning objectives

After reading this chapter, the student should be able to

I. Describe the evidence-based dentistry concept.

II. Describe the hierarchy of evidence.

III. Differentiate the different clinical study types.

IV. List the evidence-based dentistry process steps.

V. Identify different outcomes.

VI. Identify different reporting guidelines.

Chapter Outline

Evidence-based dentistry concept
Clinical study designs
- Case reports and case series
- Cross-sectional study
- Case-control study
- Cohort study
- Clinical Trials
  - *Validity in clinical trials*
- Systematic review

Evidence-based practice process
- Outcomes

Reporting the results of research

EVIDENCE-BASED DENTISTRY CONCEPT

Endodontic therapy is mainly concerned about the diagnosis and treatment of pulpal and periapical diseases and injuries. As in any other medical/dental specialty, endodontic therapy, thus, entails taking several clinical decisions.

An emerging approach regarding clinical decision making is evidence-based medicine/dentistry discipline. Evidence-based medicine is "the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients." as coined by David L. Sackett et al. in 1996. In other words, evidence-based practice seeks integration of the best, current scientific research with clinical experience together with the patient's needs, values and preferences (Figure 1). Best, available scientific evidence originates from clinical research concerned with diagnostic tests, efficacy and safety of clinical interventions and prognostic factors of clinical outcomes.

According to Sackett et al., neither individual clinical expertise nor best available evidence works alone. It is important to recognize that there are different forms of skills a good clinician must develop. One example is the technical skill a clinician must gain in order to render proper treatments. Performing an adequate access cavity and identifying and instrumenting thin and severely-curved canals are just a few examples of the skills a clinician must develop that only partially can be gained from research or "reading." Therefore, attending practically-focused workshops, watching other dentists at work, performing the procedures oneself (on models and patients), and reflecting on what has been earned from the failed cases are consistently important for the development of a skillful clinician. The clinical situation also demands that the dentist exercises good clinical judgement. It can, therefore, be concluded that in dentistry, including endodontics, proper clinical care is not only based on clinical research but also on the practical skills of a craftsman, where clinical and moral judgements are integral components.

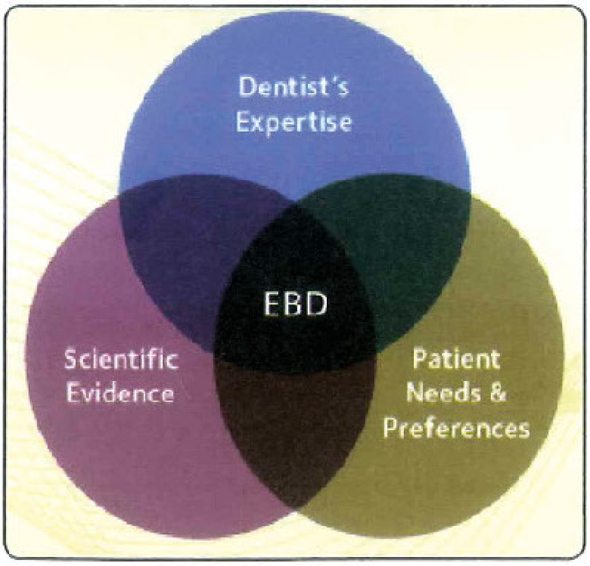


Fig. 1. Evidence-based dentistry concept.

Only the patient is the expert on how he or she feels about maintaining a tooth with or without endodontic treatment, which symptoms are tolerable, which risks are worth taking, and what costs are acceptable. Procedures for obtaining informed consent play a key role in safeguarding the patient's right to autonomous decision-making.

According to the American Association of Endodontists (AAE), evidence-based endodontics integrates the best research with clinician expertise and patient values.

CLINICAL STUDY DESIGNS

Obtaining the best available scientific evidence is facilitated by being acquainted with the hierarchy of evidence (Figure 2).

Clinical studies are mainly classified into experimental and observational studies. Experimental clinical studies mainly include clinical trials (randomized or non-randomized). Observational clinical studies mainly include cohort studies, case-control studies and cross-sectional studies.

Fig. 2. Hierarchy of evidence.

CASE REPORTS AND CASE SERIES

These two types of descriptive observational studies that document unusual occurrences of outcomes constitute the most common types of articles in medical journals.

A simple method of clinical research is the description of clinical cases, which may show unique or unusual features of a disease or outcome of therapy. It is the only means by which specific or, even, unexpected clinical events can be described. The limitation of such case presentations is, however, that evidence on efficacy, outcome rate and prognosis cannot be transmitted.

Case series are an extension of case reports, in that they are a description of a small number of individuals that have a similar experience with regards to a particular outcome and disease, rather than a documentation of just a single case as seen in case reports. Series of cases are more common and may provide better information. Larger groups of patients with a particular disease or condition subject to treatment are studied. The efficacy of the tested clinical procedure, however, cannot be proven better or equal to any other method due to the lack of a control group. In essence, case series represent more tentative than conclusive observations. Hence, case studies and case series are best utilized to develop hypotheses rather than for testing hypotheses.

CROSS-SECTIONAL STUDY

Cross-sectional are observational studies that assess the relationship of a particular disease with an exposure at the same time. In addition to being quick and inexpensive, these studies give rise to potential relationships between the exposure and outcome, but no causal inference could be made because researchers cannot be fully assured that the exposure resulted in the outcome, or was a consequence of the outcome. Therefore, these studies are usually used before other analytical, observational or experimental studies when little knowledge is available about the association of the particular outcome with the exposure under investigation.

CASE-CONTROL STUDY

Case-control studies, also, belong to the arsenal of methods for clinical research in endodontics, however, there are very few of them in the endodontic literature. It is a type of observational studies wherein cases with a particular outcome and controls that do not have the same outcome are first selected, and exposure assessment (contributing or causative factors) is done retrospectively.

Case-control studies are less costly compared to prospective cohort studies. They are fairly easy to conduct, relatively inexpensive, require shorter times for data collection and are appropriate in studying rare diseases. A significant drawback is the difficulty in obtaining critical information about the exposure status over time. It is, also, difficult to find a good control group in these studies and selection bias is, therefore, always a concern. Recall bias is another common problem. All of this causes the case-control study to be placed fairly low in the hierarchy of evidence for clinical research (Figure 2).

COHORT STUDY

Cohort refers to a group of patients and a cohort study is an observational study that follows an exposed cohort compared to an unexposed cohort to determine the incidence of a given outcome. This can be prospective (concurrent) or retrospective. A large sample of patients can be assembled for follow-up examinations.

Cohort studies can allow multiple outcomes as a result of a given exposure to be investigated within the same study. Treatment protocols assigned to different clinics can, furthermore, be used for comparison purposes then patients are checked on a regular basis. This study design has the advantage of allowing the inclusion of general dentists and, therefore, may reveal aspects of endodontics of which we have very little understanding. A problem is that these studies are expensive, time-consuming, and require careful attention to detail. Regardless of the care taken to choose the control group, selection bias is always a concern.

CLINICAL TRIALS

Randomized controlled trials (RCTs), unlike the preceding study designs, are true controlled experiments. Well-controlled RCTs, which are frequently referred to as the "gold standard" of research, can provide the strongest evidence of causation. Two or more groups of subjects receive different interventions and are followed forward in time and at some point are compared using an outcome measure. An important feature of RCTs is that patients are allocated to test and control procedures in a strictly randomized manner. To be appropriate, an RCT, also, requires a pre-calculated minimal number of patients to be included in order to ensure that a statistical difference between the test and the control procedure can be ascertained. RCTs are indeed powerful tools as many of the biases that affect non-randomized trials can be eliminated.

Nevertheless, RCTs have a number of potential weaknesses that make them inappropriate to be conducted for some studies. RCTs require long time to conduct. There are, also, high costs involved. Careful planning is, therefore, required and good training of the operators and continuous control of the procedures in both the test and control groups must be maintained. A single RCT (even if meticulously conducted) may not be sufficient to provide good evidence due to possible differences in study methods at different settings. RCTs can raise some ethical concerns if the potential benefit of the tested treatment or procedure is large enough that the subjects of the control group may be deprived of. Because of the strict eligibility criteria and loss to follow-up, RCT sample size requirements are difficult to attain and maintain with limited external validity of results.

Validity In Clinical Trials

Validity of research refers to its credibility and truthfulness in answering the research question. Internal validity of research is mainly evaluated through its methodology, while external validity refers to its generalizability.

Enhancing the validity of research entails minimizing the sources of potential errors. Two main sources of errors could occur on undergoing clinical trials, namely: random errors, and systematic errors.

Random errors refer to those occurring due to chance. The observed difference between the intervention and the control group in a clinical study cannot be expected to represent a true difference because of the random variation between the groups being compared. Statistical tests help to estimate how well the observed difference approximates the real difference.

There are two main approaches in assessing the role of chance in clinical studies, hypothesis testing and estimation. With hypothesis testing, statistical tests are conducted to calculate the probability that the observed result was by chance. This calculation may result in both false positive and false negative statistical errors. A Type I error relates to the conclusion of an effect of the tested procedure that does not exist in reality, while a Type II error means that there is a positive effect which the data failed to show the acceptable size of the risk for errors of both. It is customary to set the risk for Type I errors at 1% or 5%. For Type II errors, a considerably higher risk of error is normally accepted and the probability is usually given at 20%.

In order to avoid statistical errors, sample size is an important concern. A calculation should, therefore, be carried out prior to the onset of a study in order to analyze how many patients are needed to avoid a Type II error.

Systematic error (deviation from truth) is also known as bias. Different types of bias can occur in clinical studies. Selection bias arises when comparisons are made on groups that differ in ways other than the factors under study. Groups of patients often differ in many ways by age, sex, general health, and severity of disease. If the outcome is to be compared for two groups that differ on a certain variable e.g the type of instrument used for cleaning and shaping but are dissimilar in any other way and this difference itself is related to the outcome of interest, the comparison between the groups will be biased. Randomization is the best way to overcome these difficulties. Performance bias occurs when the care provided to the different groups is different; blinding, whenever possible, to participants and caregivers is, thus, recommended. Detection bias occurs when outcomes are differently determined across groups; blinding, whenever possible, to assessors is, thus, recommended. Measurement bias arises when the means or methods of measurement are different among the groups of patients (e.g. radiographic technique).

SYSTEMATIC REVIEW

Systematic reviews are a special type of review article that can be considered to provide the highest level of evidence when several similar randomized controlled trials on the same clinical question are utilized.

Systematic reviews, unlike textbook chapters or narrative reviews, require careful planning and inclusion of methods that minimize bias and random error. The methods must then be transparent in order to allow other researchers to replicate the results and reach similar conclusions. Meta-analysis is the statistical analysis used in a systematic review where data can be pooled for quantitative in addition to qualitative data synthesis.

EVIDENCE-BASED PRACTICE PROCESS

Application of evidence-based dentistry in practice is achieved through a process comprising the following steps: 1) formulation of an answerable research question (PICOT format); 2) finding the best available evidence; 3) appraising this evidence; 4) applying the evidence, then 5) assessing the consequences of such application.

One of the fundamental skills required for evidence-based practice is the asking of well-built clinical questions. By formulating an answerable question to focus your efforts specifically on what matters. These questions are usually triggered by patient encounters which generate questions about the diagnosis, therapy, prognosis or etiology. A good starting point is the use of the PICOT concept which stands for population/participants/problem, intervention, and control/comparator procedure and outcome measure. The PICO model can also be adopted for both planning as well as for evaluating individual studies.

The second step involves finding the relevant evidence. This step involves identifying search terms which will originate from the carefully constructed question, selecting resources in which to perform your search such as academic databases e.g. medline, then constructing an effective search strategy using different tools e.g. Boolean operators, controlled vocabulary and filters to control the scope of your search.

Critical appraisal skills are required to further filter out studies that may seem interesting but are weak. Use a simple critical appraisal method that will answer these questions: What question did the study address? Were the methods valid? What are the results? How do the results apply to your practice? Individual clinical decisions can then be made by combining the best available evidence with your clinical expertise and your patient's values. Such decisions should, then, be implemented into your clinical practice, and then the final step implies the evaluation of the effectiveness of your decision in direct relation to your patient. Was the application of the new information effective? Should this new information continue to be applied to practice?

OUTCOMES

An outcome in a study is the end result a study seeks to measure. Outcomes must be measureable and should, preferably, be patient-relevant. Because of their selection and training, dentists in general and scholars in particular tend to prefer the kind of precise measurements the physical and biological sciences provide; they discount others, especially with respect to research.

In medical disciplines, outcomes are assessed in four dimensions; the first dimension is physical/physiologic and is related to presence or absence of health/disease, pain, and function. The second dimension assesses longevity or survival. The third dimension relates to economics and assesses direct and indirect costs. Finally, the fourth dimension examines psychological aspects involving perceptions of health-related quality of life and aesthetics.

In endodontics, there are numerous studies concerned with the maintenance of pulp vitality, formation of hard tissue repair, elimination of microbes, quality of root fillings, and disappearance or reduction of periapical radiolucencies. Yet, relief of symptoms, retaining a functional and asymptomatic tooth in the long term, and a feeling of well being are among the important outcomes of dental care. These are central concerns of patients and dentists alike. To guide clinical decisions, reports of clinical research should, therefore, include these basic patient-centered outcomes.

Outcome measures that do not carry direct practical importance but are believed to reflect genuine outcomes are called surrogate measures. They often include physiological or biochemical markers that can be relatively quickly and easily measured and taken as being predictive of a true clinical outcome. Surrogate endpoints are often used when the observation of clinical outcomes requires long-term follow-ups. It is of importance that the correlation of the surrogate with the clinically-important endpoint be well established.

Evidence can be Patient-Oriented Evidence that Matters (POEM) or Diseased-Oriented Evidence (DOE). POEM deals with issues such as morbidity, mortality and quality of life. In contrast, DOE focuses on surrogate outcomes such as changes in laboratory or radiographic changes following treatment. In endodontics, most of the evidence is of the DOE type.

REPORTING THE RESULTS OF RESEARCH

Complete and consistent reporting of research results is important. In order to improve reporting quality of the results of the different types of research, reporting guidelines have been developed. Reporting guidelines are statements intended to advise authors reporting research methods and findings. They can be presented as a checklist, flow diagram or text, and lay out what is required to give a clear and transparent account of a study's research and results. These guidelines are prepared through consideration of specific issues that may introduce bias, and are supported by the latest evidence in the field. Among the commonly-known reporting guidelines are: SPIRIT (Standard Protocol Items: Recommendations for Interventional Trials) 2013 statement, for reporting protocols of clinical trials; CONSORT (Consolidated Standards of Reporting Trials) 2010 statement, for the reporting of randomized clinical trilas; The STROBE (Strengthening the Reporting of Observational studies in epidemiology) statement, for the reporting of the observational studies (cross-sectional, case-control and cohort studies); ARRIVE (Animal Research: Reporting of In Vivo Experiments), for the reporting of animal studies; STARD (STAndards for Reporting of Diagnostic Accuracy), for reporting of diagnostic accuracy studies; The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) statement, for reporting systematic reviews and meta analyses.

Chapter review Questions

1. Enumerate the steps of the evidence-based dentistry process.
2. What is the difference between cohort studies and case-control studies?
3. Define the following terms: outcome, surrogate endpoint, PICOT concept.

References

- Bader JD. Systematic reviews and their implications for dental practice. Tex Dent J 2004; 121: 380 –7
- Bergenholz G, Kvist T. Evidence-based Endodontics. Endod Topics 2014; 31: 3-18
- Equator network. http://www.equator-network.org/.
- Hargreaves KH, Cohen S. Cohen's Pathways of the pulp. 11th ed. Mosby El Sevier, 2016.
- Oleckno WA. Essential epidemiology: principles and applications. Prospect Heights: Waveland Press, Inc., 2002:252.
- Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence-based medicine: what it is and what it isn't. BMJ 1996; 312: 71–2.
- Siwek J, Gourlay ML, Slawson DC, Shaughnessy AF. How to write an evidence-based clinical review article. Am Fam Physician 2002; 65: 251– 8.
- Torabinejad M, Bahjari K. Essential elements of evidenced-based endodontics: Steps involved in conducting clinical research. J Endod 2005; 31: 563-9